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CONCEPTS AND PRACTICES IN THE ASSESSMENT OF HUMAN PERFORMANCE IN AIR FORCE SYSTEMS

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DUNLAP AND ASSOCIATES, INC.

NO CFSTI

SEPTEMBER 1965

AEROSPACE MEDICAL RESEARCH LABORATORIES
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
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700 - November 1965 - 18-369-773

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FOREWORD

This report was prepared by Dunlap and Associates, Inc., Darien, Connecticut, for the Training Research Division, Behavioral Sciences Laboratory, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, under Contract AF 33(615)-1754. The report summarizes the information obtained for the first of a two-phase program to prepare a handbook for the assessment and evaluation of human performance in Air Force Systems. As such, this report provides an overview of the techniques applicable to and the current practices in the assessment and evaluation of human performance. This research was initiated in September 1964 and completed in April 1965.

The report was prepared under Project 1710, "Training, Personnel and Psychological Stress of Bioastronautics," Task 171006, "Personnel, Training and Manning Factors in the Conception and Design of Aerospace Systems." Dr. Gordon Eckstrand was the project scientist and Mr. Melvin Snyder was the task scientist. Dr. James Keenan, the principal investigator, was assisted by Dr. Treadway Parker and Mr. Henry Lenzycki in the authorship of this report. The contract monitors were Mr. Sidney Gael and Mr. Steve Heckert of the Behavioral Sciences Laboratory.

Grateful acknowledgement is made of the assistance by many persons who provided graciously of their time, information, and facilities during the data gathering for this report. Specific acknowledgement to these colleagues and their affiliations is made in Appendix V to this report.

This technical report has been reviewed and is approved.

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ABSTRACT

This report describes the current practices and evaluative aspects of human performance assessment in Air Force Systems. The human performance test programs for thirty-four systems and subsystems representing the major types of systems (aeronautical, electronic, missile, and space) used by the Air Force are reviewed. For these systems, the major functional areas covered include: (1) Air Force policies, directives, requirements, and constraints concerning the development and assessment of system tests and human performance; (2) the behavioral sciences approach to, and technology for, assessing human performance; and (3) Air Force practices in assessment of human performance. Throughout, the systems context, within which human performance is conceived and evaluated, is emphasized. Consequently, the techniques within the behavioral sciences for examining human performance conceptually and empirically in the system test environment is a particularly practicable part of the report. The report is supported by many useful tables and charts, excerpts from test directives pertinent to human performance assessment, and approximately 600 categorized references.

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LIST OF ABBREVIATIONS

ADC	-Air Defense Command
AFFTC	-Air Force Flight Test Center
AFLC	-Air Force Logistics Command
AFM	-Air Force Manual
AFMDC	-Air Force Missile Development Center
AFMTC	-Air Force Missile Test Center
AFR	-Air Force Regulation
AFSC	-Air Force Specialty Code
AFSC	-Air Force Systems Command
AGE	-Aerospace Ground Equipment
AIR	-American Institutes for Research
AMD	-Aerospace Medical Division
APGC	-Air Proving Ground Center
ARL	-Aeronautical Research Laboratory
ASD	-Aeronautical Systems Division
ATC	-Air Training Command
BSD	-Ballistic Systems Division
D&A	-Dunlap and Associates, Inc.
EN	-Environment
ESD	-Electronics Systems Division
EQ	-Equipment
HE	-Human Engineering
JTS	-Job Training Standard
MGE	-Maintenance Ground Equipment
MIL	-Military Specification
MRL	-Aerospace Medical Research Laboratories (Reports)
NASA	-National Aeronautics and Space Administration
OGE	-Operating Ground Equipment
OJT	-On-the-Job Training
PEA	-Personnel-Environment-Activity (Unit)
PED	-Personnel-Equipment Data
PERT	-Program Evaluation and Review Technique
PS	-Personnel Subsystem
QOR	-Qualitative Operational Requirement
QQPRI	-Qualitative and Quantitative Personnel Requirements Information
RFP	-Request for Proposal
ROC	-Required Operational Capability

LIST OF ABBREVIATIONS (continued)

SAC	-Strategic Air Command
SAGE	-Semi-Automatic Ground Environment
SAIM	-Systems Analysis and Integration Model
SCF	-Satellite Control Facility
SDC	-System Development Corporation
SOR	-Specific Operational Requirement
SPO	-System Program Office
SSD	-Space Systems Division
TAC	-Tactical Air Command
TDR	-Technical Documentary Report
TEA	-Task Equipment Analysis
TEL	-Training Equipment List
TEPI	-Training Equipment Planning Information
TERG	-Training Equipment Requirements Guide
UC	-User Command (USAF)

PRACTICES IN THE ASSESSMENT OF HUMAN PERFORMANCE IN AIR FORCE SYSTEMS

I

OVERVIEW, PROCEDURES AND FRAMEWORK OF THE REVIEW

A. Overview of the Report

1. Objectives

This report was written as an interim review, a progress report, of findings concerning methods, techniques, and practices for assessing human performance. It is part of a two-phase research program for the development of a technical handbook for measuring and evaluating human performance in Air Force systems.

2. Perspective

Human performance is regarded as an interaction unit, the P. E. A., that is, personnel (P) in the system environment (E) (which includes other personnel, equipment and ambient conditions) carrying out some mission-oriented activity (A). Systems are defined as organizations of such interactions. These "P. E. A." interactions are postulated as the focal units of system and human performance assessment.

The assessment process is visualized in two or three general steps: analysis of needs for information concerning human performance, acquisition of additional, empirical information concerning performance, and evaluation of the data in terms of the need/use for it. There are needs and uses for evaluative information continuously during the four life stages of Air Force systems. A large body of requirements-documents is available to structure the development and systematic application of this information to system design, test, and evaluation. A variety of practices are currently used in the description and evaluation of human performance in the systems of the U. S. Air Force.

3. Content

This report discusses three major topics: (1) Air Force requirements concerning the development and assessment of system and human performance, (2) the methodology and technology of the behavioral sciences for assessing human performance, and (3) current uses of this technology in Air Force systems as illustrated by a review of available information concerning test programs in selected systems. Reference and source reports used in this review are appended.

4. Limitations

The discussions herein are based upon (1) the perspectives (as summarized briefly in this section) of the technical handbook for the assessment of human performance, and (2) reference material made available to us during the study for selected Air Force test activities. This effort, strictly speaking, neither evaluates what information is available nor purports to cover all activities and techniques (used or available for use) in the assessment of human performance.

The opinions concerning the focus and conceptual aspects of assessing performance are those of the authors, and do not necessarily report the thinking of the scientists consulted or the studies reviewed.

B. Procedures of the Review

1. Sources of Information

Several sources of information were used in this study. These were:

a. U.S. Air Force requirements-documents concerning the development and management of man-machine systems.

b. Behavioral science and systems engineering studies methodologically related to man-machine performance assessment.

c. Test and evaluation planning and test report documents for selected Air Force systems.

d. Cognizant personnel, military and civilian, active in the management, development, and testing of man-machine systems and subsystems.

Approximately six hundred documents, studies, and methodological reports were reviewed during this study. These reports varied with respect to the human performance being investigated, the type of military system and its stage of development, the approach as well as the disciplines represented in the investigating team, and in the goals of the specific assessment project.

Conferences and discussions were held with approximately sixty military and civilian scientists at various Air Force and Contractor locations engaged in man-machine system development and evaluation. These

discussions generally were structured toward the information and clarifications deemed necessary to reach a refined, sophisticated, and yet practical assessment methodology as well as to survey current practices in measuring human performance. Our own experiences with system and human performance evaluations influenced the discussion of other scientist's experiences. During this phase, the conceptual approach of the technical handbook was examined and iterated, and progressive changes were made to reflect the state of the art in the assessment of human performance. The handbook will profit from the information derived during this study: this report anticipates the perspectives and emphasis of the technical handbook.

2. Review of Requirements for Assessing Human Performance in Air Force Systems

The policies and directives of the Air Force concerning the management, development, and testing of military systems were reviewed systematically during this study. The major sources and types of such information are listed below.

- Air Force Regulations
- Air Force Manuals
- Air Force Specification Bulletins
- Air Force Systems Command Regulations
- Air Force Systems Command Manuals
- Air Force Systems Command Program Management Instructions
- Air Force Systems Command Division Exhibits
- Military and Federal Standards
- Military Specifications

In general, documents were reviewed which represent current requirements for developing Air Force systems, for developing the personnel subsystems of those systems, for testing Air Force systems, subsystems, and equipment, and for testing the personnel subsystem in particular.

3. Review of Illustrative Methodologies for Assessing Human Performance in Air Force Systems

Having established, by way of the review of requirements documents, the context for assessing human performance, a search was then made of techniques illustrative of current techniques and practices in the behavioral sciences and in the development of Air Force systems, relating to the assessment of human performance.

a. Review of Behavioral Sciences Technology

From the methodological viewpoint, the behavioral sciences offer useful ways of conceiving about man-machine systems, and of collecting empirical information and drawing conclusions about human performance. Much of this technology has, of course, been brought to bear on military and other governmental projects. It is likely, however, that there are new techniques under development and/or old techniques thus far relatively untried which are of potential use in the assessment of human performance. And there may be fresh perspectives on the application of the behavioral sciences to the task of assessing human performance, particularly in the early stages of system life, that require statement. Accordingly, a systematic review of the behavioral science technology was conducted, following a mapping adapted from Barmack (3). Books and periodical literature, as well as Government-sponsored research studies, were sought within this schema of the fields and subfields of the behavioral sciences. The schema itself is presented in Appendix I. Four major fields, and the basic and applied research subfields within each, were used to structure the survey of the behavioral science literature.

The first major field was named human performance studies and was broken down into two basic research subfields, namely, individual performance, and group performance. Some twenty-six topics were allocated between these basic research subfields. Similarly, applied research concerning human performance was divided into two subfields, human engineering, and team-system performance. Eighteen study areas were covered in the latter two subfields.

Three other major research fields were identified as related to the study objectives. These were personnel research studies, human support and maintenance studies, and economic analysis and management activities. Personnel research studies were expected to illustrate methods for relating system and human performance to individual and group skills, training and to training curricula, etc. Studies in the field of human support were expected to illustrate techniques for studying performance as a function of life support, equipment, shelter and environmental variables. Finally, economics, considered as a behavioral science, was expected to yield ways of describing and diagramming human performance and of relating it to the cost-effectiveness and value of the system.

b. Review of Air Force Systems

Thirty-four Air Force systems and related systems and subsystems[1] were reviewed during this study. These man-machine systems were selected to provide:

1) Representation of the major types of systems under development and test by Air Force Systems Command.

2) Representation of current and relatively recent systems within each type of system.

3) Overview of plans, tests, analyses, and reports illustrative of techniques for investigating human performance as a function of interfaces with system equipment, personnel, procedures, and/or environment.

4) Illustration, as far as possible, of test and evaluation activities during the conceptual, definition, acquisition, and operational stages of system life.

Table I summarizes the types of systems and specific systems within each type on which information was collected during this study. For the most part, the designation used for a system depended not so much on the equipment characteristics of the system (since, from this point of view, some systems would not be different from others) as upon the name of the division of Air Force Systems Command which has the responsibility for acquiring the system.

C. Conceptual Framework for this Review

The information that was collected in this study and the way in which it was organized was affected by a priori perspectives on what human performance means and the development and evaluation of human performance in Air Force systems. These perspectives are discussed briefly here, together with the resulting expectations for the methodology of human performance assessment.

1. Considerations Concerning Human Performance

Operationally considered, human performance is the interaction of system personnel, equipment, environmental conditions, and procedures.

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[1]N.A.S.A. projects and some subsystems within Air Force systems were also reviewed during this study.

Table I. Systems, Subsystems and Programs Reviewed During This Study[a]

Type of System, Subsystem, or Program[b]			
Space	Aeronautical	Missile	Electronic
Gemini B (1962-64)	B-47 (1952)	WS-315A - Thor IRBM (1958-59)	425L (1958-59)
Satellite Control Facility (1964)	B-25 (1953-54)	SM-68 - Titan I ICBM (1958-63)	416L (1959-61)
Apollo (1964-65)	AN/APQ-24 (1954)	WS-107A-1 - Atlas ICBM (1959-61)	465L (1960-64)
Manned Orbiting Laboratory (1964-65)	B-52 (1960-61)	TM-76B - Mace (1960)	480L (1960)
	B-58 (1960-61)	WS-107C - Titan II ICBM (1963-64)	473L (1961)
	Helicopter Flight Simulator (1962)	Program 279 (1963)	412L (1961-63)
	CH-3C Helicopter (1963)	WS-133 A, B Minuteman ICBM (1962-65)	433L (1962-63)
	C-141 (1963-64)		431L/482L (1962-64)
	F-4C (1964)		416M (1963-64)
	F-5A/B (1964)		483L (1963)
	D. O. R. A. F-111A/B (1965)		466L (1963)
			496L (1963)

[a]Including time period of reported human performance studies.

[b]Names and descriptions of these systems are presented in Section IV, pages 62 through 88.

Human performance is circumscribed and directed by the mission of the system. A system is an organisation of interactions oriented toward the accomplishment of a specified goal or set of goals.

Studying human performance in systems requires detailed information concerning the interactions among human components (system personnel), system equipment (e.g., displays, controls, test points), environmental conditions (e.g., ambient lighting, noise, temperature), and activities (system procedures).[2] The assessment of human performance involves the comparison of what is known about these various interactions with what is expected or required of the same interactions by the mission of the system.

Figure 1 presents a useful summary or model of the functioning of the individual human component in relating to the system environment. It also summarizes the aspects of human performance, some, or many of which, were expected to be under investigation in the systems surveyed and/or the literature reviewed.

2. Considerations Concerning an Overall Assessment Methodology

A generalized assessment process, schematized in Figure 2, was used as a frame of reference in surveying and organizing the various activities involved in the evaluation of human performance. Accordingly, it was expected that the assessment of human performance would proceed in three phases. The first of these phases generally includes the identification of a specific need for information concerning some aspect of human performance and the setting about to acquire the information. The need for information varies from system to system and from one development stage to the next, but typically it is related to decisions regarding automation, equipment, design, etc. What is usually required is an estimate of some aspect of performance, that is, information predicting the characteristics of one interaction or another involving system personnel. Typically, this results in setting up a formal, empirical situation in which the predictions and expectations concerning performance can be examined under specified conditions. This phase of the assessment process can be expected to include a variety of techniques and tools for describing and predicting performance, and for planning or selecting test situations designed to provide the information.

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[2]Human performance may be described functionally as a "PEA" interaction, that is, personnel (P), in an environment (E), which includes other personnel, equipment and ambient conditions, carrying out some activity (A).

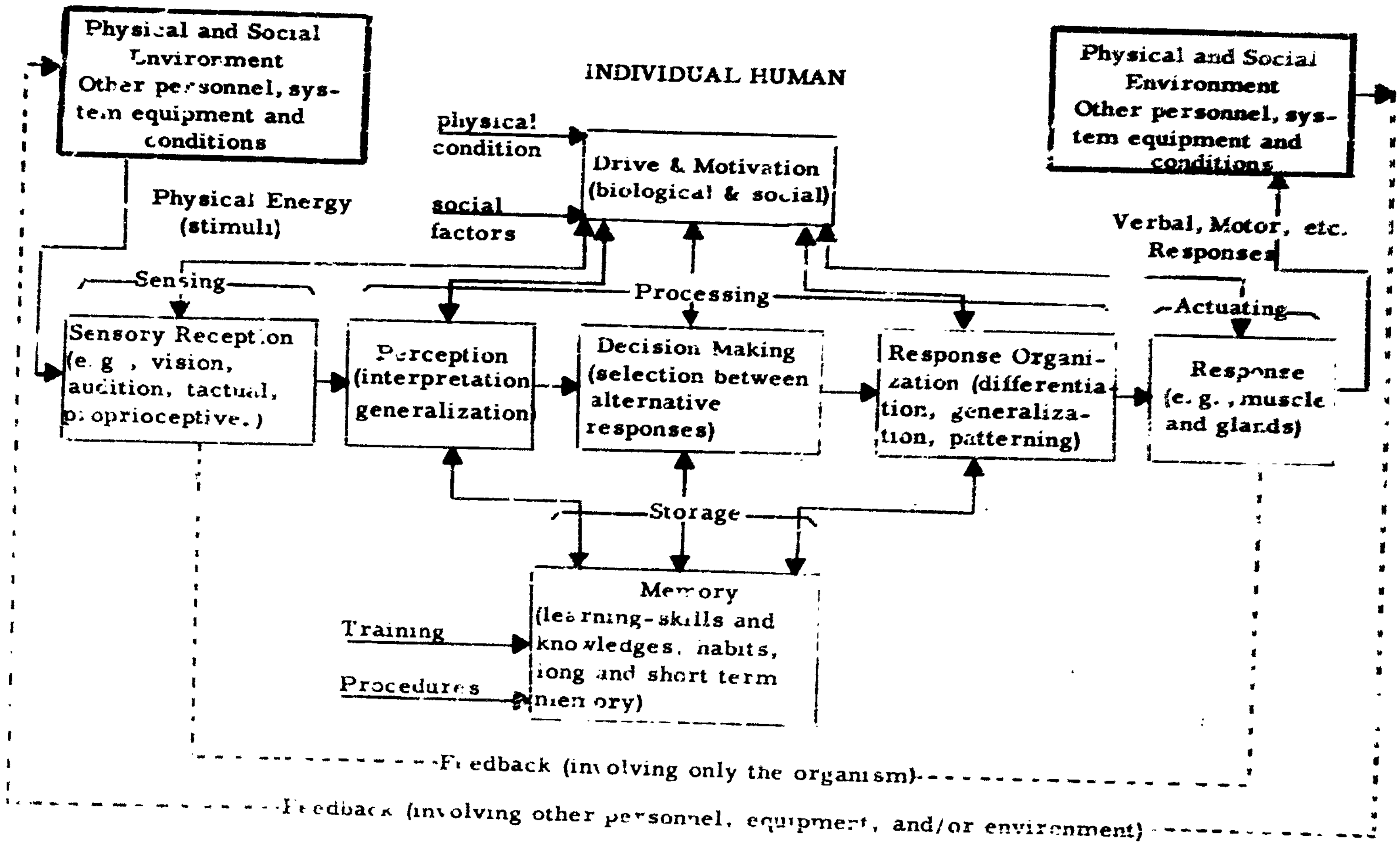

Figure 1. Generalized Behavioral Functions of the Personnel-Environment-Activity Unit for Human Performance Assessment

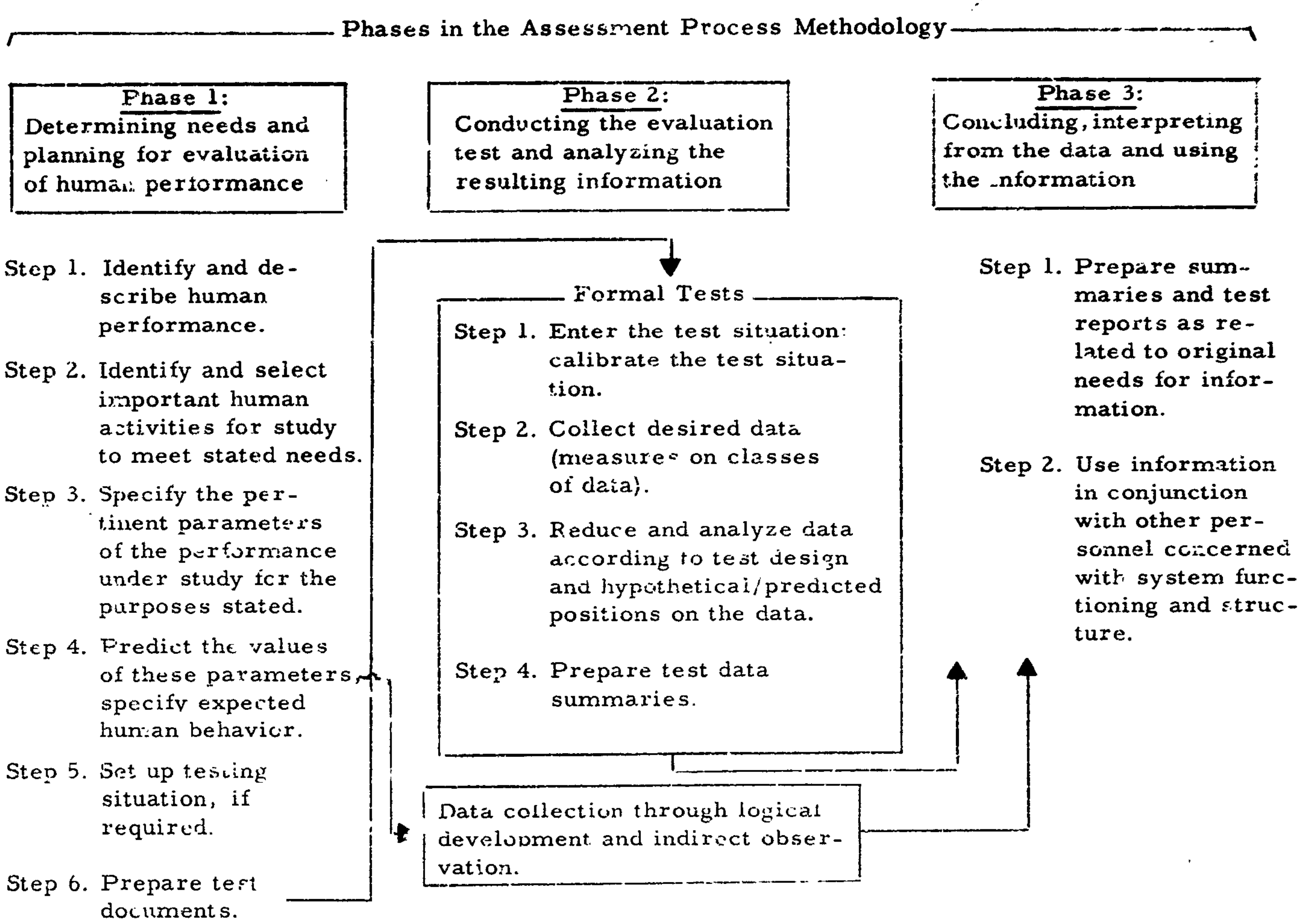

Figure 2. General Framework for the Assessment of Human Performance

The second phase of the hypothesized assessment process includes the conduct of the tests planned in phase one and the use of assorted techniques for collecting data. These techniques are variations of indirect or direct human observation. A variety of test situations can be set up to provide for the observation of human performance, e.g., simulations, field trials. Human observation of human performance is usually structured and programmed, instrumented by the use of checklists, rating scales, photography, recorders, etc. This phase also includes the reduction and analysis of information and the use of descriptive and inferential statistics, expert judgment, etc.

The preparation of test reports in diverse formats and the use of the test information occur in the third phase of the hypothesized assessment process.

3. <u>Considerations Concerning Needs for Assessment During System Development</u>

This study was principally concerned with the developing Air Force system and the needs for and accomplishments in assessing human performance as the system grows. The generalized system growth process may be thought to consist of four stages:

- Stage One--requirements determination
- Stage Two--determination of design consequences
- Stage Three--design and integration of the system
- Stage Four--formal test and evaluation prior to operational use

The process is iterative, a series of approximations in which predictions concerning human performance are intimately related to various systems engineering activities and decisions. This perspective, detailed in Table II, was the context of our inquiry into techniques used by systems and human factors engineering personnel in conceiving about and dealing with human performance during the stages, particularly the early stages, of system development.

D. Organization of this Report

This report is divided into five sections supported by appendix and reference materials.

Section I introduces the report and describes the study perspectives, procedures, framework and limitations.

- Section II contains a summary of Air Force Requirements for 1) managing and developing Air Force Systems, 2) developing the personnel subsystems of Air Force Systems, 3) testing Air Force Systems, subsystems and equipments, and 4) testing the personnel subsystems.

- Section III contains an overview of the scientific literature as it relates to the assessment of human performance, and summarizes current perspectives on analytical, data collection, and evaluative techniques.

- Section IV reviews assessment programs and techniques in selected Air Force systems, most of which information was secured from SPO and contractor personnel and/or test documents.

- Section V briefly summarizes and concludes the report, with emphasis given to the implications of this information for an overall assessment methodology.

Table II. Generalized System Engineering and Human Performance Assessment Activities During the Development of the Air Force System

Typical System Engineering Activities

Requirements Determination →	Determination of Design Consequences →	Design and Integration of System →	Formal Test and Evaluation
Mission requirements determination and analysis Identification of operating, weight, space, and other constraints Performance of gross trade-off studies Definition of system and subsystem types, hardware techniques and performance, reliability, and maintainability goals Determination of information transfer requirements throughout the system Establishment of operational, maintenance, and support concepts Development of system evaluation requirements	Evaluation of alternative design concepts with respect to preceding step (e.g., analog vs. digital, mechanical vs. electrical) Determination of facilities requirements; performance of detailed trade-off studies Preparation of system and subsystem specifications	Reliability-maintainability analysis and prediction Determination of system and subsystem test and checkout requirements Logistic support analysis Generation of system evaluation plans, and of performance, reliability and maintainability reporting requirements and procedures Establishment of quality assurance and equipment modification programs Establishment of documentation (i.e., technical manual) requirements	Conduct of system test Continuing review of quality assurance program results and of early performance, reliability, and maintainability reports Definition of spare parts procurement, inventory, and transportation requirements; initiation and/or approval of minor modifications Analysis of installation problems and reports; initiation and/or approval of minor modifications Analysis of individual test and evaluation reports; initiation and/or approval of minor modifications Continuing review of system performance, reliability and maintainability

Table II. Generalized System Engineering and Human Performance Assessment Activities During the Development of the Air Force System (continued)

Typical Activities Involving Assessment of Human Performance

Requirements Determination →	Determination of Design Consequences →	Design and Integration of System →	Formal Test and Evaluation
Establishment of personnel implications and constraints (e.g., number, type, reenlistment rate, training capabilities, operating environment)	Analysis of information transfer requirements throughout the system	Translation of control and display requirements into hardware requirements	Recommendations of modifications to designs or procedures for operation and maintenance
Contribution to operational and maintenance concepts and maintainability goals	Detailed assignment of subsystem functions to personnel and equipment for each alternative design concept	Specification of location and environment for operator stations	Familiarization of operational personnel with system
Participation in gross trade-off studies	Translation of information transfer requirements into display, control, workplace and processing requirements for each alternative design concept	Selection and design, where required, of control and display components	Review of installation reports from human factors standpoint; recommendations of minor design changes
Gross automation studies; assignment of functions to personnel and equipment	Evaluation of each with respect to human factors (e.g., implications for number and types of personnel, training, job aids, man-machine interface design, data processing requirements)	Design of operator panel, consoles, and workspace	Review of engineering test and evaluation reports from human factors standpoint
Gross division of duties among personnel	Preparation of man-machine portions of subsystem specifications	Specification of operating and maintenance procedures for normal and non-normal modes of operation	Evaluation of prototype system from human factors standpoint, personnel subsystem testing and evaluation
Determination of implications for manning and training		Participation in system evaluation planning	Determination of training adequacy and recommendation of changes
Determination of implications for system evaluation		Personnel manning and training requirements determination	
		Establishment of training courses	

II

REVIEW OF REQUIREMENTS FOR ASSESSING HUMAN PERFORMANCE IN AIR FORCE SYSTEMS

A. Introduction

Throughout system development, numerous decisions are made, as a matter of course, concerning the functioning and structure of the system The process, anticipated in the foregoing section, may be thought of as a series of successive decisions about organizing the set of personnel-environment-activity interactions called the system.

In order to get the job done as thoroughly and effectively as possible, system development is guided by an elaborate set of government directives and requirements documents. These documents contain the policies and needs of the Air Force and other governmental agencies as well as consensus agreements, between the defense agencies and contractors, concerning standards of good management and engineering.

This section overviews and summarizes the major Air Force requirement documents that structure (1) the management and development of the Air Force system; (2) the development of a personnel subsystem within the over-all system; (3) the testing and evaluation of the system, subsystems, and various equipments; and (4) the testing and evaluation of human performance in developing systems. Information in this section reflects the weapons system development policies in effect during the 1964-1965 period and those which refer more specifically to human performance assessment. This information provides the context within which evaluations of human performance in Air Force systems typically take place.

The major requirements of the Air Force in the above areas are contained in different types of Air Force and military documents including the following:

- Air Force Regulation (AFR)
- Air Force Manual (AFM)
- Air Force System Command Regulation (AFSCR)
- Air Force System Command Manual (AFSCM)
- Air Force System Command Program Management Instruction (AFSCPMI)
- Exhibits originating with Divisions of Air Force Systems Command (e.g., BSD Exhibits)
- Military and Federal Standards
- Military Specifications

The contents of such documents are represented in the discussions which follow. The major references are tabled later in this section and are keyed to activities of particular relevance to the assessment of human performance. A representative list of the reference requirement documents is included in Appendix II.

B. Requirements for Managing and Developing Air Force Systems

Various documents contain the policies of the Air Force for weapons system management and development. The principal documents are Air Force Regulations 375-1, 375-2, 375-3, and 375-4. An excellent overview of the Air Force Systems Management Concept is contained in AFR 375-4. Of particular interest here are the phases within which Air Force Systems are managed and developed. Briefly, there are four phases: Conceptual, Definition, Acquisition, and Operational.

The Conceptual Phase is the period extending from the determination of a broad objective until the Office of the Secretary of Defense (OSD) approval of the Program Change Proposal (PCP) covering the Definition Phase. If the Definition Phase does not apply, the Conceptual Phase extends to the issuance of the System Program Directive (SPD).

In the Definition Phase, the technological advances resulting from the Conceptual Phase are translated into total system design requirements. The SPO/Industry team utilizing the detailed methods and procedures described in AFR 375-4 and the referenced AFSCM 375-1 and 375-5 manuals completely and fully investigates all aspects of existing technology, past studies, and possible future studies to define the requirements outlined in the SOR/OSR/ADO. The basic objective of this effort is to insure that full-scale development is not started until costs, schedules, and performance objectives have been carefully identified, evaluated against one another and a high probability established of successful completion of the Acquisition Phase.

The fundamental objective of the Acquisition Phase is to acquire the system in such a manner that the Specific Operational Requirement (SCR) or Specified Advanced Development Objective (ADO) is met while at the same time minimizing system cost, time to acquire the system, and maximizing system effectiveness. The orderly transition of system responsibility and management responsibility from AFSC to the User Command and AFLC is provided for during the overlap of the Acquisition and Operational Phases.

The Operational Phase has been established as a logical concluding step for the system acquisition cycle. The prime goal of this phase is successful system operation. Secondary goals are adequate system support by the AFLC and an orderly turnover from AFSC to the User.

These phases, taken together, describe the life cycle of the Air Force weapons system. More or less involved throughout are the Air Force

Headquarters USAF, Air Force Systems Command (AFSC), Air Force Logistics Command (AFLC), Air Training Command (ATC), and the User commands (SAC, TAC, etc.).

Figure 3 summarizes the system development phases and major activities or products of the functions within the phases of system life.

C. Requirements for Developing the Personnel Subsystems in Air Force Systems

The requirements to develop specific products and elements in support of the over-all man machine performance of the weapon system are specified in AFR 30-8. These requirements are listed in Appendix III. In summary, the Air Force requires that human performance be developed in a systematic, timely manner coordinated with the development of the system hardware and facilities. This usually requires specific attention to human performance as a function of the design of equipment, safety, layout of the work places; skills, training, number, and organization of the system personnel; type, amount, and content of training and training equipment; and operating and maintenance procedures. The systematic development of these system elements requires detailed description of the interactions of system personnel with the system environment (including equipment and ambient conditions) and the maintenance of a valid and reliable centralized body of basic descriptive information. The amount, type, and format of this information may vary from system to system. There are, however, military specifications and Air Force directives which deal directly with the requirements and preparation of integrated man-machine information for particular systems. These have been noted in the summary table at the end of this chapter.[3] The primary source of information and guidance for developing the Personnel Subsystem is AFSCM 80-3, Handbook of Instructions for Aerospace Personnel Subsystem Designers.

D. Requirements for Testing Air Force Systems

Air Force Regulation 80-14 is the controlling requirements-document for the testing and evaluation of Air Force systems, subsystems, and elements.

Important policy explanations and distinctions are made in the regulation concerning the types of tests required to support USAF research and development and system acquisition. The regulation applies to all Air Force organizations and activities. "Testing" refers to any project or program designed

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[3] The discussion of these documents, relating to individual systems or personnel subsystem elements, is not within the scope of this chapter. Our purpose here is principally to point out and describe, as briefly as possible, the broad context of performance assessment.

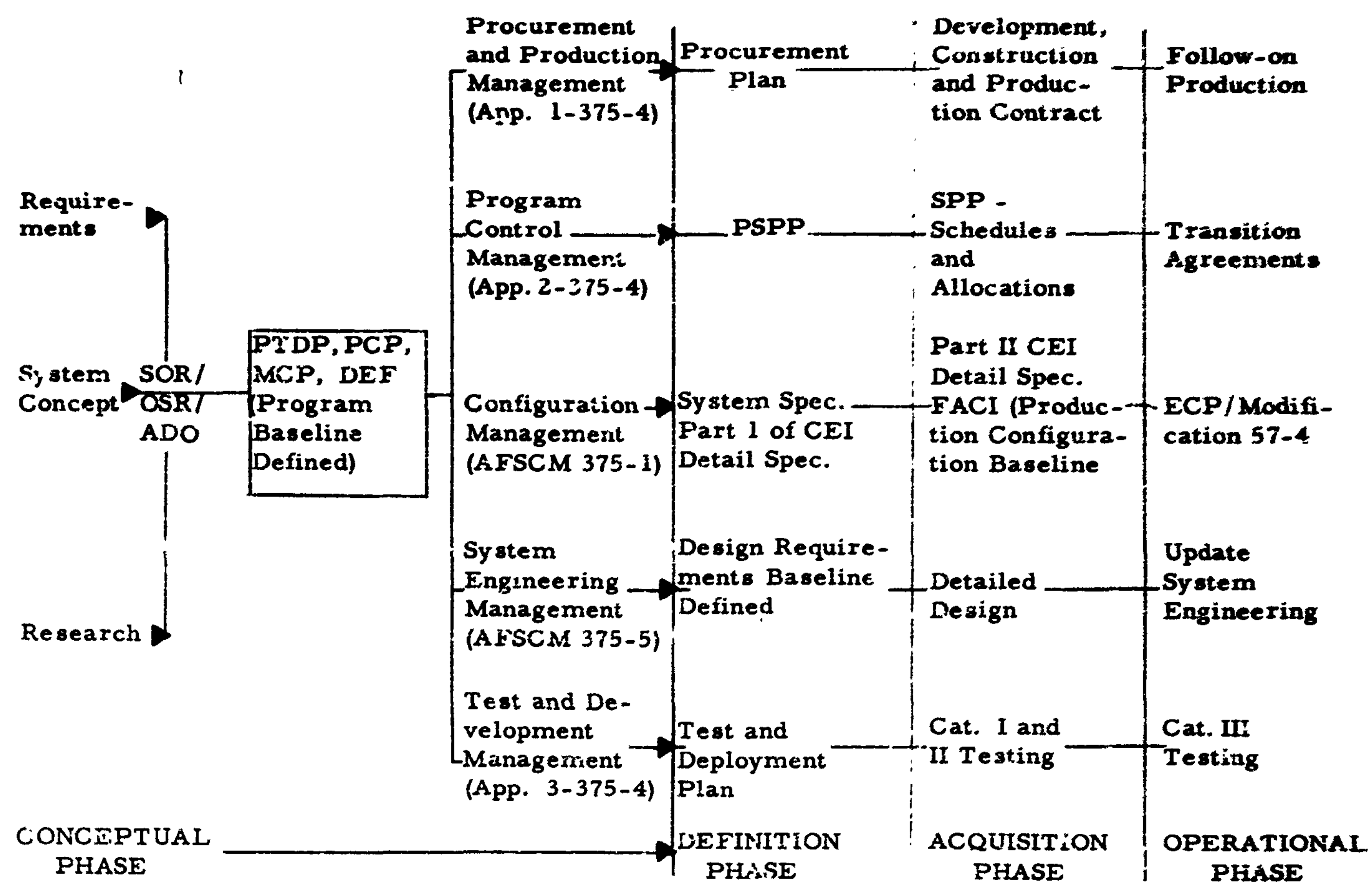

Figure 3. Summary of System Development Phases and Major Activities or Products of Functions Within the Phases. (Source: AFSCM 375-4.)

to obtain, verify, and provide data for evaluating research and development, progress in accomplishment of developmental objectives, and performance and operational capability of systems, subsystems, components, and equipment items. The term "evaluation" is construed as the review and evaluation of quantitative or qualitative data. Distinctions are made concerning types of testing. Research testing is defined in AFR 80-14 as a project designed to verify hypotheses and propose solutions to operational needs or accumulate new knowledge. Developmental testing is an integral part of the development process used to sense trends, measure progress, and verify the accomplishment of development objectives on a continuing basis. Anticipating the discussion next of human performance testing, these explanations provide the policy basis for the continuous assessment of the products and processes of the personnel subsystem.

AFR 80-14 specifies the objectives, policies, and procedures of testing and delineates three functional categories of formal tests: Category I, Category II, and Category III. Catetory I and II testing occur during the Acquisition Stage of system development. Category III testing is carried out during the early portion of the Operational Stage of the system life cycle. Four types of testing are also described in the document and are subject to the three functional catugories or phases of testing. These test programs cover the testing of weapons systems, research and development projects, engineering services, and ballistic missiles.

Excerpts from AFR 80-14 are presented in Appendix IV and in Figure 4. Additional instructions concerned with testing and evaluation are contained in other Air Force documents. AFSC Program Management Instruction 6-10 is particularly useful in defining and providing guidance on factors common to the test and evaluation of weapons systems. It presents, in relatively abbreviated form, the requirements and content for test planning, test documentation, programming resources and test items, data reduction and analysis, evaluation of test results, test reporting, and the classification of procurable items on the basis of favorable test and evaluation of the items.

E. Requirements for Testing and Evaluating the Personnel Subsystems in Air Force Systems

The systematic development of the human performance in Air Force systems, specified in AFR 30-8 and guided by other documents (see Table IV at the end of this section), includes testing and evaluation in accord with AFR 80-14. Formal coordinated testing is to be integrated with system testing and carried out from Category I through Category III until it is verified that the system can be operated, maintained, and supported by USAF personnel as intended. Formal guidance concerning the testing and evaluation of personnel subsystem products and processes that support the man-machine performance of the system is given in AFSCM 80-3. The direction is unequivocal and logical: whenever plans are made to introduce a human function

<table>
<tr><td></td><td colspan="2">DEVELOPMENT TESTING
(ACQUISITION PHASE)</td><td>FOLLOW-ON DEVELOPME</td></tr>
<tr><td></td><td>CATEGORY I</td><td>CATEGORY II</td><td>CATEGOR</td></tr>
<tr><td>ALL SYSTEMS</td><td>SUBSYSTEM DEVELOPMENT TEST AND EVALUATION

Development testing and evaluation of the individual components, subsystems and in certain cases, the complete system. In addition to qualification, the testing provides for redesign, refinement and reevaluation as necessary, including the practicality of utilizing current standard and commercial items. These tests are conducted predominately by the contractor, but with Air Force participation, evaluation and control, exercised through AFSC.</td><td>SYSTEM DEVELOPMENT TEST AND EVALUATION

Development testing and evaluation spanning the integration of subsystems into a complete system in as near an operational configuration as is practicable. Suitable instrumentation will be employed to determine the functional capability and compatability of subsystems. Category II is a joint contractor-Air Force effort under Air Force control during which the Air Force effort becomes predominant with ever-increasing operating and supporting command participation. Whenever feasible, actual test operation and maintenance should be performed by military personnel who have received formal system training. It is usually culminated with the demonstration effort required to complete the development portion of the acquisition phase of a system program.</td><td>SYSTEM OPERATIONAL TES

Testing and evaluation of operati
control and direction of the ope
shall include all components, sup
skills, technical data and proced
under as near operational condi
Suitable instrumentation will be
adequately evaluate test results
be conducted utilizing a configur
by the operating command and A
conducted in accordance with a
designed to meet the objectives o
test force size and composition w
in the Operational Test and Eval
Accomplishment may be performed
AFSC, or other available
dictate.</td></tr>
<tr><td>STRATEGIC BALLISTIC MISSILE SYSTEMS (ONLY)</td><td colspan="2">RESEARCH AND DEVELOPMENT TESTS

Component subsystem and system development under the supervision of a Service technical agency. These tests are predominantly contractor efforts, with increasing military participation leading to the demonstration that system design goals have been met under non-operational conditions

(Note: These tests are equivalent to Category I and II listed above for <u>all</u> systems.)</td><td>DEMONSTRATION AND SHA
(DASO

Tests conducted by operation
by the Service technical age
environment using operation
these tests, operational and
are refined, basic system cap
are demonstrated; and the
the system is sufficiently
intended mission

(Note. Equivalent to Categ</td></tr>
<tr><td>PARTICIPANTS</td><td colspan="2">AIR FORCE SYSTEMS COMMAND
(CONTROL)

OPERATING/SUPPORTING COMMANDS

CONTRACTOR</td><td>OPERATING C
(CONTRO

SUPPORTING C
(AFSC, AFL</td></tr>
</table>

Figure 4. Summary of Requirements for Testing Air

LLOW-ON DEVELOPMENTAL TESTS

OPERATIONAL TESTING

(OPERATIONAL PHASE

CATEGORY III

SYSTEM OPERATIONAL TEST AND EVALUATION

...ing and evaluation of ... under the ...trol and direction of the operating command. These tests ...l include all components, support items, personnel ...s, technical data and procedures and shall be performed ...er as near operational conditions as practicable ...able instrumentation will be employed in order to ...quately evaluate test results. Category III testing will ...conducted utilizing a configuration as jointly agreed ...the operating command and AFSC/AFLC. The test will be ...ducted in accordance with a specific test plan or order ...greed to meet the objectives of all participants. The ...force size and composition will be as mutually agreed ...e Operational Test and Evaluation Plan or Order. ...mplishment may be performed at Operating Command, ..., or other available installations as circumstances ...ate.

DEMONSTRATION AND SHAKEDOWN OPERATIONS (DASO)

Tests conducted by operational commands, assisted by the Service technical agency, in an operational environment using operational procedures. During these tests, operational and logistical procedures are refined; basic system capabilities and limitations are demonstrated; and the determination is made that the system is sufficiently stabilized to perform its intended mission.

(Note: Equivalent to Category III for all systems)

OPERATIONAL TESTS

A test program for exercising the operational system in as near an operational environment as possible to determine weapon system reliability and accuracy factors under representative operational conditions. This program provides for the determination of weapon system reliability and accuracy planning factors, at specified confidence levels and intervals, as opposed to the objectives of R&D and DASO test programs which are conducted for the purpose of improving these factors.

(Formerly Type III)

FOLLOW-ON OPERATIONAL TESTS

Tests conducted on a continuing basis to insure that the established reliability and accuracy factors are preserved during the life of the weapon system.

(Formerly Type IV)

OPERATING COMMAND (CONTROL)	OPERATING COMMAND (CONTROL)
SUPPORTING COMMANDS (AFSC, AFLC, ATC, etc)	SUPPORTING COMMANDS (AFLC, AFSC, ATC, IG, etc)

for Testing Air Force Systems (Source:AFR 80-14).

2

into a system, plans must also be made to test this function in relation to the rest of the system...much of this must be accomplished in early stages of system design. Wherever feasible, AFSCM 80-3 directs, personnel subsystem test data should be collected at system milestones such as design reviews, equipment revisions, demonstrations, and inspections. These may include prototype design engineering inspections, mock-ups, flight demonstration reviews, qualification testing, etc. In addition, failure and consumptive data, reports on hazards, accidents, safety, incidents, etc., must be collected and analyzed for human performance implications. AFSCM 80-3, following AFR 80-14 and other documents, also discusses the Air Force functional responsibilities for developing and testing the personnel subsystem. A copy of the manual's summary table is presented in Table III.

F. Summary of the Major Requirements-Documents

The major requirements-documents structuring the description, classification, prediction, support, and verification of required human performance in Air Force systems are presented in Table IV. The documents are listed by Air Force designation and classified in two ways: (1) pertinence to the management, development, and test of the personnel subsystem and allied topic areas, and (2) category of Air Force and Department of Defense documentation. This information illustrates the requirements that were in effect prior to or during the period of this study (1964-1965).

Table III. Air Force Functional Responsibilities for Personnel Subsystem Development (Source: AFSCM 80-3, page A. 4-5)

Item	HQ USAF	AFSC	AFLC	ATC	UC
Personnel-Equipment Data (PED)	*	***	**	**	**
Human Engineering and Life Support	*	***	*	*	*
Personnel Considerations in System Facilities	*	** (*)	**(*)	**(*)	**(*)
Qualitative and Quantitative Personnel Requirements Information (QQPRI)	*	***	**	**	**
Training Concepts	*	*	*	**(*)	**(*)
Manpower Authorizations	***	**	**	**	**
Personnel Plan	**	***	**	**	**
Training Equipment Planning Information (TEPI)	*	***	*	**	**
Training Equipment Development (TED)	*	***	*	*(*)	*(*)
Training Plans	*	*	*	**(*)	**(*)
Technical Publications	*	***	**	**	**
Personnel Subsystem Test and Evaluation (PSTE)	*	**(*)	**	**	**(*)

***Primary Responsibility **Participation *Coordination

Table IV. Illustration of Air Force Requirements-Documents Related to the Assessment of Human Performance in Air Force Systems

	Human Performance Evaluative Focus	Air Force Regulations	Air Force Manuals	Air Force Systems Command: Regulations	Air Force Systems Command: Manuals	Air Force Systems Command: Prog. Mgm't. Instruction	AFSC Division Exhibits	Military Standard	Military Specifications
	Management/Planning for Test & Evaluation (including requirements for technical data)	AFR 57-4; 65-3; 66-29, -30; 67-19; 80-5, -6, -11, -14[a], -24, -27, -28, -31, -32, -36; 161-2; 310-1; 375-1, -2, -3, -4; 400-25, -26.	AFM 11-1, 66-18, 110-9.	AFSCR 80-4, 80-23.	AFSCM 310-1 AFLCM 310-1 AFSCM 80-8, (HIMD) 80-9; 375-1, -4, -5	AFSCPMI 1-4, 2-7, 2-5; 4-2; 4-3, 4-7; 6-8; 6-10.	AFBM 60-50 (Titan WS-107A-2) AFBM 60-65A WCLDPT 60-21.		MIL-D-9310B, -9411, -9412, -26239, -70327; MIL-H-25946, -26207, 27894; MIL-T-27382, -27474, MIL-W-9411.
Personnel Subsystem Elements	Human Engineering	AFR 30-8; 53-12.	AFM 64-4.	AFSCR 80-16	AFSCM 80-1 (HIAD) 80-3 (HIAPSED) 80-5 (HIGED) 80-6 (HIAGED) 80-7 (HIAVED)		AFBM 57-8A, 60-1, WDT 57-7; BSD 61-99 (WS133B) ESDP 375-1.	803A-1; 831.	MIL-H-25946, -27894; MIL-P-25996; MIL-S-26634.
Personnel Subsystem Elements	QQPRI	AFR 26-1, -3, 30-8.	AFM 26-1; 35-1; 36-1; 66-18.				AFBM 58-18C.		MIL-D-26239.
Personnel Subsystem Elements	Training and Training Equipment	AFR 30-8; 50-19.					WDT-56-5C; AFBM 59-17.		MIL-D-26239; MIL-T-4857B, -4860, -9344, -27382, -27474, -27615.
Personnel Subsystem Elements	Life Support and Safety	AFR 30-5, -E; 58-4, 160-3; 161-2, 122-4	AFM 32-3		AFSCM 122-1		AFBM 58-19. BSD 62-79 (WS133B); BSD 62-41.		MIL-S-38130, -58077.
Personnel Subsystem Elements	Technical Orders Manual Publications	AFR 30-8, 66-7.		AFSCR 66-7, -8			WDT 56-5, AFBM 58-9, -9A.	218	MIL-C-9883; MIL-H-6814; MIL-M-5474, -9864(USAF), -38701.
	Maintainability/Maint	AFR 66-1, -8, -29	AFM 66-1				AFBM 59-32 BSD 62-53.		MIL-M-26512.
	Reliability	AFR 80-5					AFBM 58-10	105; 441	MIL-R-26667, -26674, -27542.
	Test Report	AFR 80-27		AFSCR 11-2 AFSCR 80-20	AFSCM 5-1	AFSCPMI 1-5	AFBM 58-1	831	MIL-T-9107 (superseded by Mil. Std. 831)
	Test Support	AFR 23-2, -6, 35-14; 40-423; 50-3, -9, 66-18, 400-26	AFM 66-18; 172-1						

[a] Major documents related to human performance testing are underscored

III

OVERVIEW OF THE TECHNOLOGY OF THE BEHAVIORAL SCIENCES FOR ASSESSING HUMAN PERFORMANCE

A. Introduction

This section is written principally as a point of departure for an understanding of the technology of the behavioral sciences for assessing human performance in military, particularly Air Force, systems. It contains (1) our perspectives on the broad behavioral science technology applicable to studies of human performance in the system context and a schema useful for mapping the relevant experiences and literature of the behavioral sciences; (2) a review of selected areas of the behavioral science technology relevant to the description and evaluation of human performance in the military system context.

B. Relevant Areas of Research and Technology in the Behavioral Sciences

There are five areas of information and methodology in the behavioral sciences which are particularly relevant to the assessment of human performance in Air Force systems. We derive these five areas or foci by elaborating on the perspective, presented in Section I, that studying human performance involves focussing on some system PERSONNEL, in the system ENVIRONMENT (which includes other system personnel, system equipment and the ambient system conditions), carrying out some selected ACTIVITY or set of activities in execution and/or support of the system mission. The five types or aspects of performance are described briefly here.

The first "type" has to do with the functioning of the individual operator, or maintenance technician, etc., with his capacities and limitations. More specifically, this means the individual's sensing, sensory organization, responding, drive/motivational, storage/memory, and feedback/adaptive functioning (see Figure 1 in Section I for a basic model of individual human functioning). The second aspect of human performance, conceived in personnel-environment-activity terms, is the inter-personnel interaction(s). Study of interpersonal performance involves, for example, consideration of social structure, communication networks, authority arrangements, roles and group syntality. The third "type" of performance, widely studied in the typical human factors or human engineering program, is the interaction of system personnel and the various system equipments. Studies of these interactions

generally focus upon levels of automation, man-machine dynamics, control-display-behavior relationships, etc. The fourth "type" of performance suggested by the personnel-environment-activity dimensions of human performance is the interaction of system personnel and the ambient system conditions, for example, illumination, sound, air conditioning, sensory and social isolation. And the fifth interaction of relevance in the assessment of human performance is between system personnel and the system activities, procedures, and doctrine.

The interactive personnel-environment-activity concept of human performance, in addition to making for a summary of the subject matter of the applicable behavioral science technology, also helps identify the behavioral science specialists, disciplines and published literature.

Personnel specialists and those interested in the impact of individual human differences upon system effectiveness typically do or can attend to the performance, capacities, and limitations of individual system personnel. They can be assisted by the familiar QQPRI, the training, and the proficiency evaluation specialists.[4]

Social psychologists, group dynamicists, unit proficiency analysts, cultural anthropologists, game theorists, and such specialists can and often do contribute to the analysis and understanding of the inter-personnel interactions.[5]

Human factors engineering, industrial design, and such disciplines typically are involved with the personnel-equipment interactions.[6] Life support scientists, safety engineers, and physiologists are among the professionals whose technology is applicable to the interaction of system personnel and the ambient system conditions.[7]

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[4] see, for example, references 2, 21, 73, 78, 79, 84, 88, 91, 97, 99, 105, 107, 108, 111, 112, 124, 133, 135, 138, 141, 143, 150, 157, 160, 171, 172, 183, 184, 332, 337, 359, 363, 364, 419.

[5] see, for example, references 6, 12, 42, 59, 77, 81, 82, 103, 110, 125, 152, 163, 289, 324, 376, 401.

[6] see, for example, references 40, 51, 52, 63, 66, 80, 92, 98, 99, 119, 131, 168, 171, 172, 185, 186, 312, 314, 406, 444, 446.

[7] see, for example, references 94, 140, 152, 177, 196, 341, 374, 393, 438, 445.

Work methods and industrial engineers, training professionals, and handbook specialists are involved typically in the development of the desired personnel-activity interactions in the operation and maintenance of a military system.[8]

As Air Force systems develop through the conceptual, definition, acquisition, and operational phases of their life cycles, a number of evaluative activities take place with reference to the interactions among system personnel and the system environment and procedures, activities and/or doctrine (see Table II in Section I for a summary of system and human performance studies). In general, these activities (1) analyze human performance in terms of system requirements, (2) collect empirical information to enable prediction and/or verification of system/human performance, and (3) evaluate and use such information. This assessment process is supported by a repertoire of behavioral science studies principally to be found in four major fields (3). The fields are (1) human performance, (2) personnel research, (3) human support and maintenance, and (4) economic analysis and management.

Figure 5 schematizes the preceding discussions and summarizes the approach which we found useful in the methodological review of the behavioral science literature for assessing human performance in Air Force systems. Figure 6 relates the schema of this methodological review to the personnel-environment-activity concept of human performance. We regard the development and reporting of this mapping or plan for searching/reviewing the relatively vast behavioral science literature as important to this overview and as potentially useful to those involved in the assessment of human performance.

C. Major Technologies of the Behavioral Sciences Relevant to Human Performance Assessment in Air Force Systems

The foregoing discussion indicates the broad content and methodological areas or fields of the behavioral sciences relevant to the assessment of human performance in military systems. The development of the behavioral sciences to their present day involvements in system development is generally important and interesting, but is not discussed here (see, for example, references 13, 21, 48, 96, 142, 382, and 385). Rather, we

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[8] see, for example, references 5, 8, 60, 69, 78, 83, 85, 93, 97, 99, 105, 120, 122, 123, 128, 139, 147, 148, 158, 159, 163, 165, 166, 174, 176, 305, 428, 442.

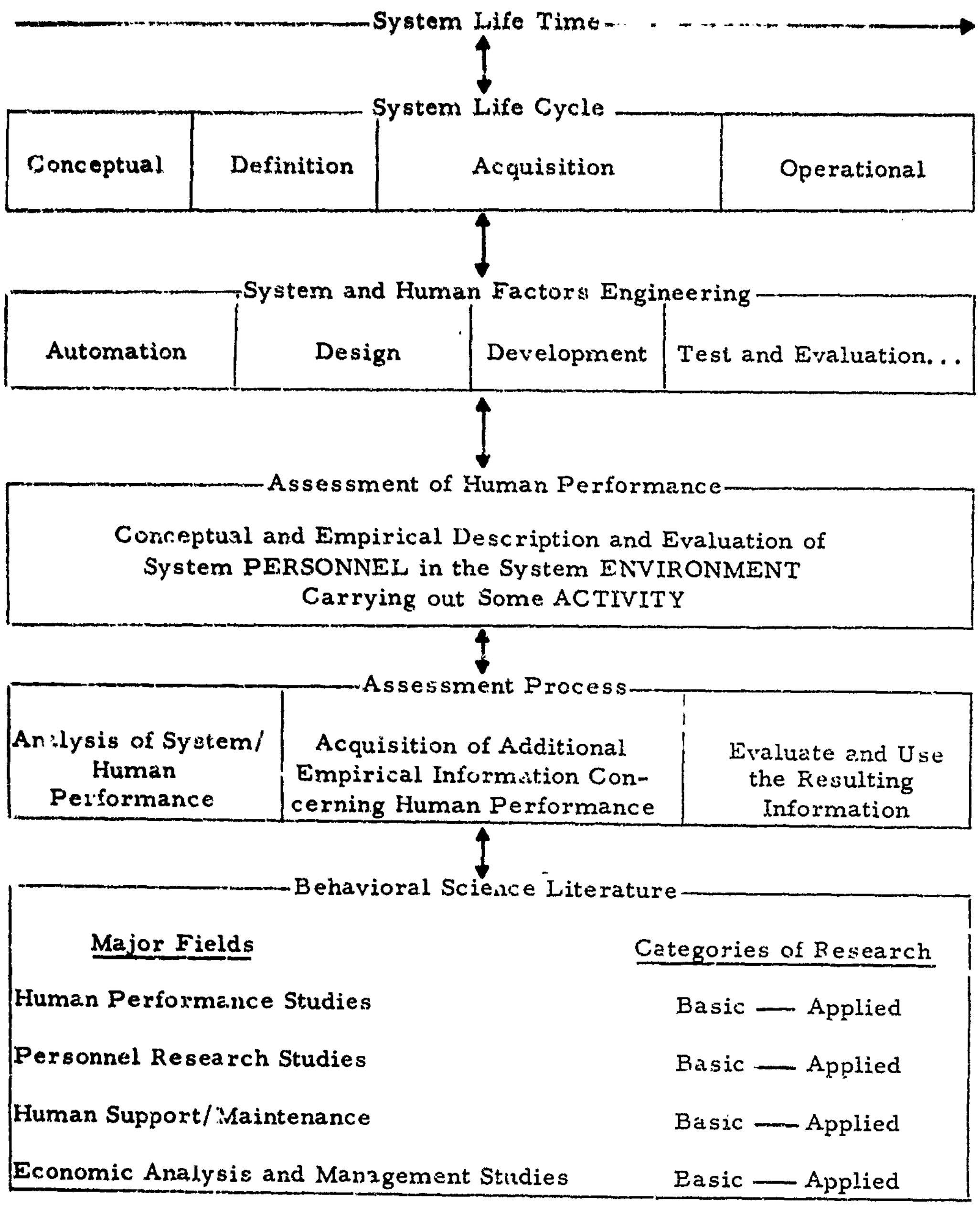

Figure 5. Approach to the Methodological Review of the Behavioral Sciences for Assessing Human Performance in Air Force Systems

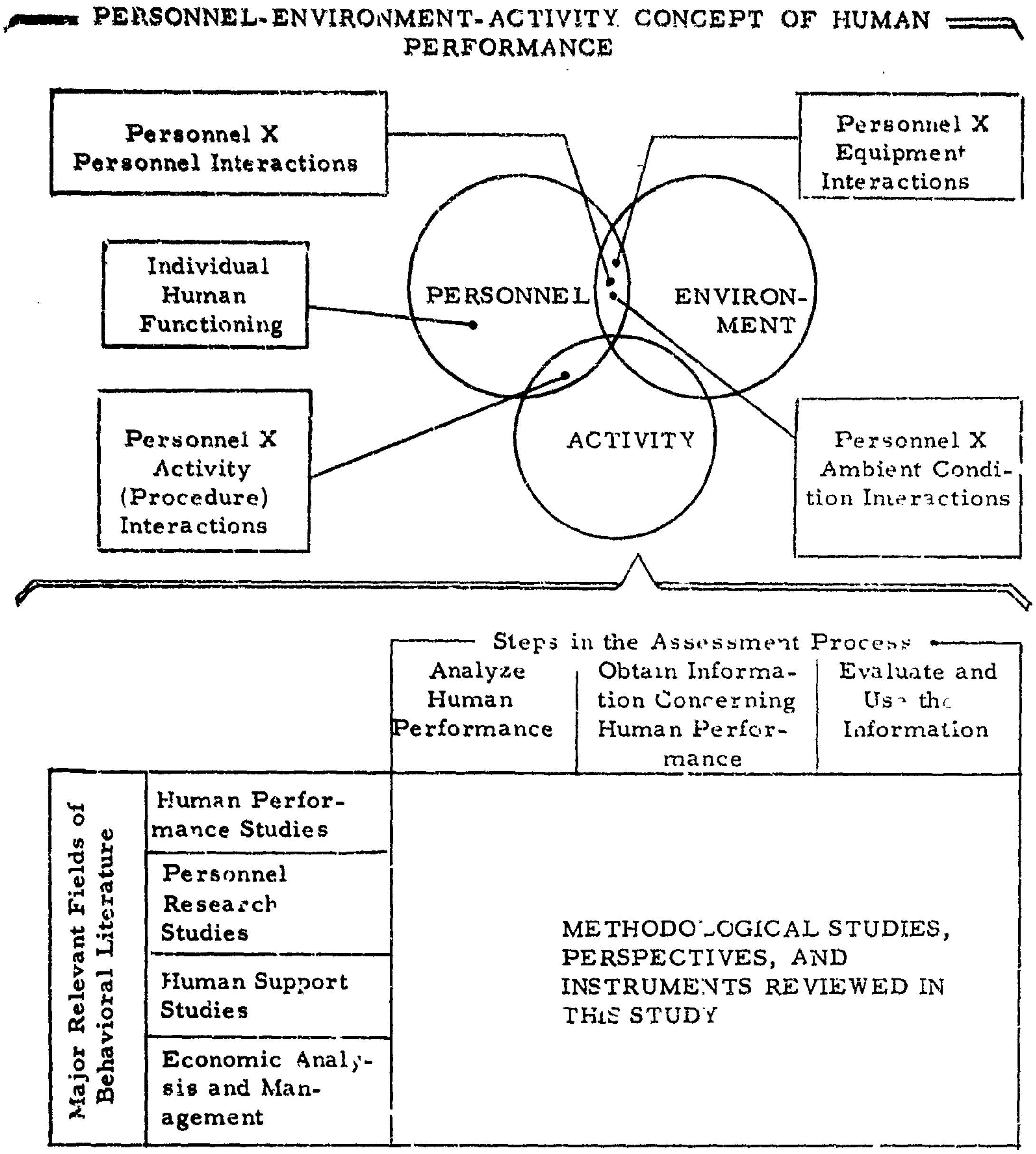

Figure 6. Refined Mapping of the Methodological Studies, Perspectives, and Instruments of the Behavioral Sciences Reviewed During This Study

wish to draw attention to what we believe to be the two technologies within the behavioral sciences most useful to the study of human performance in the context of the military and industrial system. These technologies include (1) practices for conceptually assessing human performance, and (2) practices for empirically assessing human performance. By the conceptual assessment of human performance, we mean the description, understanding, and evaluation of human functioning prior to the actual manning, by representative personnel, of the system roles and positions. Conceptual assessment usually takes place during the early system life stages when, largely, the projected system personnel, system equipment, and system environment are unavailable, and/or not yet developed or obtained. Empirical assessment, on the other hand, refers to the collection and analysis of information concerning observable system personnel in the real or simulated system environment carrying out some system activity or procedure. Typically, empirical assessment is carried out at system simulation facilities, prototype test facilities, and operational system sites. Empirical assessment activities generally are not possible or opportune during early system development stages, e.g., conception, definition. They take place usually during the acquisition and operational stages of system life.

1. Techniques for the "Conceptual Assessment" of Human Performance

The study of human performance during the early system life stages requires the modeling and systematic gaming of the expected role(s) and functioning of the human component in the system. Largely, this examination of human performance entails conceptual analyses, paper and pencil studies both quantitative (mathematical) and non-quantitative (verbal, diagrammatic, etc.).

Historically, behavioral scientists have not frequently used mathematical models in their study of human performance. This would appear true not so much because the subject matter is not amenable to quantitative analysis and expression but, probably, because the practitioners of the behavioral sciences have not been accustomed to think and communicate in mathematical terms. This is not surprising: mathematics has developed as the handmaiden of the physical sciences. On the other hand the behavioral scientist has used narrative and diagrammatic, (e.g., flow diagrams), techniques to communicate about the subject matter of human performance. It should be pointed out, however, that these, as with mathematical models, are modeling techniques, committing to paper symbols and relations among symbols that, in effect, stand for some aspect of performance. Currently, in the behavioral sciences, a variety of mathematical and verbal modeling techniques is used in the study of human performance and should be noted here

regarding the study of the "conceptual man" at the early stages of system life.

a. Quantitative Heuristic Techniques

The extension of classical mathematical analysis, concerned with a few variables and their continuous functional interrelationships, to the behavioral sciences has been marked with some success, e.g., the widespread use of classical, quantitative correlational techniques, and with certain problems. The first of these problems concerns the traditional necessity in classical mathematics to isolate a relatively few variables. The study of a few variables works well in carefully contrived laboratory settings but is patently difficult in the typical man-machine system study. The second weakness, (and the principal one for this review), of classical mathematics is that it has not successfully coped with the problem of determining the important variables: the classical method works best when it can deal with variables that are given, known in advance. And, yet to be useful in early system design, modeling techniques must allow the discovery or recognition of aspects of human functioning to which specific attention should then be given. In brief, the import of classical mathematical techniques in the striving of the behavioral sciences to understand and plan for humans in system context is that they have been and continue to be powerful tools for deducing relations among performance variables but they are not particularly useful for discovering performance variables.

More recent mathematical techniques have been developed which can contribute to discoveries and hypothetical positions regarding human performance. For the most part, these techniques are heuristic: they provide concepts with which the system designer can work, with which he can describe, classify and deduce properties of the man-environment-activity interaction. Examples of such approaches are topological theory, graph theory, and the theory of games. These theoretics represent departures from the classical type of thinking symbolized by the expression $x = f(y)$. Instead, they focus upon descriptions of organized systems and provide the anatomy of the human performance of interest. These approaches help identify performance variables which can then be studied by ordinary mathematics. For example, the network of interpersonal relations in an operating crew or military organization can be schematized by a linear graph (in the graph theoretic approach)[9] and the social properties involved in the group's

[9] See Harary and Norman (126) for an examination of the potential use of graph theory in the behavioral sciences.

performance can be expressed as mathematical properties of the graph. The usefulness of doing this is that heretofore unsuspected variables or characteristics of them may be opened up for study and that the system designer is provided with suggestions as to how to proceed further.[10]

b. Non-Quantitative Heuristic Techniques

The foregoing paragraphs point up the usefulness of quantitative functional modeling, using the newer mathematical approaches, in the conceptual assessment of human performance. It should be noted, however, that most system and human performance analyses start and continue with non-quantitative, principally verbal, descriptions. This section contains a tabulation of an illustrative group of techniques which have been developed and found useful for examining qualitatively (verbally, diagrammatically, etc.) the interactions among system personnel, system environment and system activities.

Current practices in the non-quantitative, heuristic examination of human performance seem to be the result of two lines of development in the behavioral sciences: (1) the description, analysis, and classification of human work, and (2) the rating, evaluation, and comparison of incumbents and jobs. Work description and analysis includes, historically, numerous approaches toward operationally defining and structuring the content of human work (e.g., job description and job analysis),[11] the process, workplace and movements of work (e.g., time and motion analysis),[12] and the hierarchies of jobs and incumbents (e.g., occupational analysis and classification).[13] Of particular note for this review is the post-World War II application of work-analytic techniques to the planning for and design of Air Force systems[14] and the comparatively recent development of the U.S.A.F. Personnel

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[10] Useful discussions of mathematical-psychological methodology are contained, for example, in Rapoport (163) and Luce et al. (141).

[11] see, for example, references 10, 90, 93, 94, 98, 99, 100, 101, 105, 113, 120, 137, 147, 151, 153, 158, 164, 174, 181, 381, 383, 442.

[12] see, for example, references 83, 120, 123, 153.

[13] see, for example, references 142, 165, 183, 265, 278.

[14] see, for example, reference 151.

Subsystem approach based in large part upon the construction and use of function- and task-analytic information.[15]

Table V presents and summarizes the major non-quantitative techniques useful for examining human performance heuristically. The contents of the techniques are described along the dimensions of the personnel-environment-activity concept of human performance. The techniques have been classified according to format: graphic, tabular, narrative, and lists and rating scales. The graphic group includes diagrams, charts, profiles and matrices. The narrative and tabular categories are self-explanatory; the lists and rating scales group includes checklists some of which are accompanied by rating scales.

Referring to the table, the items identified under each of the general categories of system activity, system personnel, system equipment and environment should explain themselves However, some explanation is required for the two-level category of activity. Actually, four levels can be inferred by combining the information in the "level" and "relationship" categories. If the function level is checked and the relationships shown are "within," then the level of analysis handled by the technique concerns subfunctions. If the "task" level is checked along with the "within" relationship, it can be inferred that the technique analyzes subtasks or elements. Additional clarifications related to items within a specific technique are contained in the footnotes accompanying the table.

The content analysis indicates that there are considerable overlaps among techniques and that techniques differ very often in appellation rather than in content. For example, task analysis techniques, such as the Operational Sequence Diagram, Information-Decision-Action Chart, Task-Equipment Analysis, and Position Descriptions are all very similar. Differences among techniques are due principally to the format, the purposes and interests of the analyst, and the application of the technique at different stages of system development.

Environmental information is, in general, not included in approximately half of the techniques illustrated in this review. For some techniques, perhaps, the information is not pertinent to the analysis or it is analyzed elsewise. It is surprising, however, that human task analytic techniques do not contain such information as a matter of rule.

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[15] see, for example, references 4, 13, 19, 20, 21, 22, 23, 29, 34, 37, 38, 39, 45, 46, 48, 56, 57, 62, 63, 66, 68, 70, 71, 75, 86, 95, 96, 114, 116, 130, 131, 138, 151, 167, 173, 199.

Table V. Content Analysis of Typical Non-Quantitative Heuristic Techniques Used to Examine Human Performance in System Operation

	TYPICAL TECH-NIQUES[a]	SYSTEM ACTIVITY													SYSTEM PERSONNEL										
		ID			Level		Relationship		Duration		Other				ID		Level		Relationship		Abilities				
		Operation	Maintenance	Support	Function	Task	Within	Between	Stated	Scaled	Incident	Reqmts or Criteria	Criticality	Location	Title	AFSC	Single	More than One	Within	Between	Sensory	Motor	Mental	Physical	Error Probability
Graphic	Opni Seq Diagram	x				x				x	x			x	x		x	x	x	x	x	x	x		
Graphic	Time Line Charts	x			x	x		x		x	x	x[b]		x	x		x		x		x	x			
Graphic	Syst Anal & Integration	x	x	x	x	x	x	x	x						x		x	x	x	x	x	x		x	
Graphic	Integrated[c] Task Index	x	x			x		x		x	x					x	x	x	x	x					
Graphic	Mission Profiles	x	x	x	x			x		x	x	x													
Graphic	Link Analysis	x				x	x	x			x				x[d]		x	x	x	x	x	x			
Graphic	Func. Flow Diagram	x	x	x	x			x	x	x															
Graphic	Team Activity Chart					x		x		x	x				x[d]			x	x	x					
Graphic	Mult Proc. Chart	x				x	x	x		x	x				x			x		x		x			
Graphic	Man-Mach. Chart	x				x	x	x		x	x				x		x		x			x			
Graphic	Info-Decis-Actn Chart	x				x	x	x		x	x				x		x	x	x	x	x	x	x		

	TYPICAL TECH-NIQUES[a]	SYSTEM EQUIPMENT											ENVIRON-MENT		
		ID		Level				Descrip.		Other					
		Name	Mil. Nomenclature	System	Subsystem	Equipment	Component	Functional	Physical	Value Ranges	Malfunc. Prob.	Location	Hazards & Safety	Ambient Conditions	Constraints
Graphic	Opni Seq Diagram	x				x	x	x				x			
Graphic	Time Line Charts	x					x	x							
Graphic	Syst Anal & Integration	x				x	x		x	x	x	x	x	x	x
Graphic	Integrated[c] Task Index	x				x	x								
Graphic	Mission Profiles	x		x	x			x		x			x	x	x
Graphic	Link Analysis	x[d]				x		x							
Graphic	Func. Flow Diagram	x	x	x	x			x				x			
Graphic	Team Activity Chart	x					x	x							
Graphic	Mult Proc. Chart	x					x	x				x			
Graphic	Man-Mach. Chart	x					x	x				x			
Graphic	Info-Decis-Actn Chart	x				x	x	x							

a - References for each technique are contained in Table VI.
b - Does not appear on all time-line charts.
c - Accompanied with a time-line chart.
d - Utilize a number or symbol code ascribable to a position title or equipment name.

Table V. Content Analysis of Typical Non-Quantitative Heuristic Techniques Used to Examine Human Performance in System Operation (continued)

TYPICAL TECH-NIQUES[a]	SYSTEM ACTIVITY													SYSTEM PERSONNEL												SYSTEM EQUIPMENT											ENVIRON-MENT		
	ID			Level		Rela-tionship		Dura-tion		Other				ID		Level		Rela-tionship		Abilities						ID		Level			De-scrip.		Other						
	Operation	Maintenance	Support	Function	Task	Within	Between	Stated	Scaled	Incident	Reqmts or Criteria	Criticality	Location	Title	AFSC	Single	More than One	Within	Between	Sensory	Motor	Mental	Physical	Error Probability	Name	Mil. Nomenclature	System	Subsystem	Equipment	Component	Functional	Physical	Value Ranges	Malfunc. Prob.	Location	Hazards & Safety	Ambient Conditions	Constraints
Tabular: Task Eqpt Anal (TEA)	x	x			x	x	x	x	x	x				x		x	x	x	x	x	x	x	x	x	x	x			x	x	x		x	x	x			
Task Anal of Proced.[e]	x	x			x	x					x			x		x	x	x		x	x	x	x	x	x	x				x	x		x	x	x	x		
Form B & Form C_1[f]	x	x			x	x		x		x	x	x	x	x		x	x	x	x	x	x	x				x											x	
Posn Equip Task Sum.	x	x			x		x	x					x		x	x	x	x	x							x	x	x	x	x					x			
Task Anal Wrk Sheet	x	x			x	x		x				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x	x	x	x	x			x	x	x
Sys Req & Cap Anal	x				x	x					x					x		x		x	x			x	x				x	x	x							
Maint & Hand Data		x		x	x		x	x		x	x									x	x				x				x	x	x	x			x	x		
Opnl & Sup Data Col Sht	x			x		x	x													x	x	x	x		x					x	x	x				x		x
Perf Obsvn Rec Form[g]	x				x	x	x	x								x	x	x	x					x	x					x	x							
Perf Factor Form	x	x	x		x	x																																
Task Anal for Error ID	x	x			x	x																		x	x				x		x					x		

e - Gross and sub-task analyses are treated as one technique.

f - Form B is used for operational tasks; Form C_1, for maintenance task, does not identify criticality of activity.

g - Identifies abilities by operator skill level code.

Table V. Content Analysis of Typical Non-Quantitative Heuristic Techniques Used to Examine Human Performance In System Operation (continued)

	TYPICAL TECH-NIQUES[a]	SYSTEM ACTIVITY													SYSTEM PERSONNEL											SYSTEM EQUIPMENT											ENVIRON-MENT		
		ID			Level		Rela-tionship		Dura-tion		Other				ID		Level		Rela-tionship		Abilities					ID		Level				De-scrip.		Other					
		Operation	Maintenance	Support	Function	Task	Within	Between	Stated	Scaled	Incident	Reqmts or Criteria	Criticality	Location	Title	AFSC	Single	More than One	Within	Between	Sensory	Motor	Mental	Physical	Error Probability	Name	Mil. Nomenclature	System	Subsystem	Equipment	Component	Functional	Physical	Value Ranges	Malfunc. Prob.	Location	Hazards & Safety	Ambient Conditions	Constraints
Narrative	Task Anal Cont Fdbck	x				x	x					x		x	x		x		x		x	x	x		x	x				x	x	x		x	x		x		
	Position Descriptn[h]	x	x			x	x	x	x		x	x	x	x	x	x	x		x	x	x	x	x	x	x	x				x	x	x		x	x	x	x	x	x
	Job Des-criptions	x	x			x	x								x		x		x		x	x	x	x		x				x		x					x	x	x
Lists & Rating Scales	Eqpt Eval Guide (EEG)																									x					x	x		x		x			
	Chklist of HE Eval																									x		x	x		x	x	x	x	x	x	x		x
	Phys De-mands frm[i]	x	x			x	x		x						x		x		x		x	x															x	x	x
	Job Psy-chograph	x			x			x							x		x		x				x			x				x									
	Worker Char.Form	x			x			x							x		x		x		x	x	x	x		x				x							x	x	

h - Duties and Tasks are described in a tabular format.

i - Also includes data in narrative format.

Summary descriptions of these techniques are contained in Table VI. In addition to the description, the typical uses of the information and the major proponents of the technique are given. The list of proponents and references is not exhaustive and is intended principally to convey the general direction of the literature with respect to verbal-heuristic analyses of human performance.

2. Techniques for the "Empirical Assessment" of Human Performance

Thus far, this section has summarized the technology of the behavioral sciences for examining human performance while the performance is largely conceptual. The emphasis which follows is upon practices for examining human performance empirically, that is, for planning, conducting, and using a test situation for assessment purposes. System personnel in the system environment carrying out some system activity are in focus during the empirical test as they are in the previously described paper-and-pencil analyses of human performance.

There are many good reference works on scientific research and the conduct of behavioral science studies. Some are philosophical treatises on the scientific method (for example, 14); some discuss the practice of the scientific method (for example, 197); many are compendia of methods and findings.[16] Overviewing these materials here is difficult; presenting what they have to say in great detail is not intended. In general terms, however, they advise on and illustrate principally three areas of the technology of the behavioral sciences for empirically assessing human performance. These areas are (a) planning the test situation, (b) collecting information concerning human performance, and (c) reducing, analyzing, and using the obtained information.[17]

a. Planning the Test Situation

Planning the test situation usually involves the choice and statement of a researchable or testable objective, searching and reviewing relevant literature (as available), understanding the assessment process in

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[16]for example, 118, 121, 142, 155, 179, 190, 199 (experimental psychology); 6, 12, 103, 254 (social psychology); 4, 13, 16, 19, 20, 21, 22, 23, 29, 34, 37, 38, 39, 45, 46, 48, 56, 62, 63, 66, 68, 71, 75, 86, 95, 96, 114, 116, 130, 131, 138, 151, 167 (human factors engineering)

[17]Wilson (197) indicates that "many scientists owe their greatness not to their skill in solving problems but to their widsom in choosing them." The many guidelines and references on designing tests and studies notwithstanding, there seems to be little available advice and few specific techniques for knowing when or that a test situation is required.

Table VI. Summary Descriptions, Reported Uses and Principal Proponent(s) of Major Non-Quantitative Techniques to Describe Human/System Performance

Techniques	Summary Description	Reported Uses	Proponents	Refs.
Operational Sequence Diagrams (OSD)	This technique presents information-decision-action sequences that a system or its component subsystems will undergo in order to attain prescribed mission objectives. It employs both symbolic and verbal material to effect a pictorial-scenario display which systematically structures the tasks to be performed. It has been used successfully to establish sequence of operations requirements between subsystem interfaces at various levels of system analysis, to identify difficult or error-like situations that can be traced to inadequate hardware, procedures or communication link construction, to establish requirements for training programs and devices, to detect operator overload, and to provide information relevant to the design of controls, displays and workplace layout.	Design, Layout, Training, Procedures, Evaluation.	Dunlap and Associates, Inc.	37 90 102 137 193
Time-Line Charts	Movement is the essence of time-line charts, which can be described generally as graphical representations of the magnitude of a variable as observed over intervals of time. Typical time-line charts, as used in system analysis by human factors specialists, describe system activities on the ordinate and their relationship to	Allocation, Design, Layout.	Amer. Inst. for Research and others.	70

Table VI. Summary Descriptions, Reported Uses and Principal Proponent(s) of Major Non-Quantitative Techniques to Describe Human/System Performance (continued)

Techniques	Summary Description	Reported Uses	Proponents	Refs.
Time-Line Chart (Continued)	a time scale representing the beginning and ending of a phase or segment of the total mission time. Some charts identify the types of tasks (e. g. , continuous, discrete) by coding the time-line representative of each task. For each activity (function, task, subtask, etc.) occurring in the mission segment, its beginning and end point and its frequency of occurrence are indicated.			
Task-Equipment-Analysis (tabular form)	The Task-Equipment-Analysis is a tabular representation of tasks and subtasks, the personnel and equipment involved, the displays, decisions, actions, and feedback present, and the frequency and duration of time involved in performance. This form of presentation and its content has been used by USAF and modified slightly by HRB-Singer to show critical values related to displayed information.	Design, Training, Procedures.	USAF, Amer. Inst. for Research, HRB-Singer.	193

Table VI. Summary Descriptions, Reported Uses and Principal Proponent(s) of Major Non-Quantitative Techniques to Describe Human/System Performance (continued)

Techniques	Summary Description	Reported Uses	Proponents	Refs.
Task-Analysis of Procedures	This technique, consisting of two major steps, first identifies gross tasks and analyzes the displays or input features, and, second, analyzes the subtasks, emphasizing the control action or response aspects of the tasks. The display analysis covers such variables as task-relevant cues to initiate the task, the critical values or stimulus differences for discrimination, the alternative choices the display may present, and the characteristic errors or malfunctions that might occur. The response analysis covers similar features and, in addition, identifies response adequacy (feedback) and the objective criteria of response adequacy.	Design, Training.	Amer. Inst. for Research	151
Task-Analysis of Continuous Feedback Skills	This is a narrative description of skills involved in a continuous feedback type of task (e. g., tracking) which involves continuous adjustments to continuously changing stimulus conditions, part of which are a consequence of the operator's adjustments. The variables identified relate to the display, decisions, controls, and the feedback mechanism. Characteristic errors and malfunctions are also identified.	Training, Design.	Amer. Inst. for Research	151

Table VI. Summary Descriptions, Reported Uses and Principal Proponent(s) of Major Non-Quantitative Techniques to Describe Human/System Performance (continued)

Techniques	Summary Description	Reported Uses	Proponents	Refs.
Form B and Form C_1	Both the B and C_1 forms are tabular techniques for recording task and task-related information and were utilized by contractors to BSD on the Minuteman program. Form B is used to describe operational tasks. Form C_1 describes maintenance tasks. Both forms identify a function, the tasks and equipment required to implement that function, the facilities requirements, and personnel information regarding skills, time to perform, number of people, and critical values.	Allocation, Training, Design, Procedures.	BSD contractors on "Minuteman"	495, 504, 505
Position-Equipment Task Summary (PETS)	The PETS is a record and report by work area of the relationships between personnel actions and end items of equipment. Indenture of end items of equipment is carried to the lowest level necessary in order to identify significant differences in personnel actions. The summary is used as a tool for ensuring compatibility among type and number of personnel required, allocation of tasks, training programs and equipment, and review of spares provisioning.	Manning, Allocation, Training, Logistics.	BSD contractors on "Atlas"	518

Table VI. Summary Descriptions, Reported Uses and Principal Proponent(s) of Major Non-Quantitative Techniques to Describe Human/System Performance (continued)

Techniques	Summary Description	Reported Uses	Proponents	Refs.
Integrated-Task-Index (ITI) With Time-Line Analysis	ITI is a record and report of the identification of tasks required to carry out system functions identified in the functional flow diagrams. It is organized and numbered to coincide with numbered functions on flow diagrams so as to show task sequences and their time phasing where applicable or otherwise list the independent unsequenced tasks. It identifies personnel by AFSC required to perform each task, incorporates a time-line analysis for those task sequences which are time-phased and, for each task listed, uses a code to indicate the status of the "detailed" analysis for that task.	Manning, Allocations.	BSD contractors on "Atlas"	518
Task Analysis Work Sheet (TAWS)	This is a record of detailed analyses of tasks approved in the ITI for such analysis. The TAWS are used to furnish detailed task analysis information for: human factors engineering evaluation of equipment operation and maintenance requirements; development of technical manuals, training equipment design; training course material; and operation and maintenance checklists. They contain information related to tasks, personnel, equipment, environment, and training and are perhaps the most inclusive of all T/A forms reviewed.	Design, Training, Evaluation, Manuals.	BSD contractors on "Atlas"	518

Table VI. Summary Descriptions, Reported Uses and Principal Proponent(s) of Major Non-Quantitative Techniques to Describe Human/System Performance (continued)

Techniques	Summary Description	Reported Uses	Proponents	Refs.
System Req. & Capabilities Anal. Form	This form is a record of system analysis activity showing the relationship among tasks, requirements, and the man-machine capabilities required to satisfy the requirements.	Allocation	Amer. Inst. for Research	162
Maintenance and Handling Data Collection Chart	This chart is a data collection form used to review systematically the functions required for equipment maintenance at various levels (locations). It identifies the support equipment required, the time and frequency of activity, and the type of maintenance required (i. e., preventive, corrective, or periodic). This chart is used in early stages of system design.	Planning, Procedures.	Amer. Inst. for Research	162
Operation and Support Data Collection Sheet	This sheet is a form used to collect and report operator and support information relative to equipment components. It identifies operator skills and knowledges required, characteristics of components, operating activities for each component, supply requirements associated with the equipment, and hazards and safety information associated with the handling and use of components and support items.	Planning, Procedures.	Amer. Inst. for Research	160

Table VI. Summary Descriptions, Reported Uses and Principal Proponent(s) of Major Non-Quantitative Techniques to Describe Human/System Performance (continued)

Techniques	Summary Description	Reported Uses	Proponents	Refs.
Checklist of H. E. Evaluation Factors (CHEEF I)	The CHEEF I is an equipment checklist used during early stages of equipment design to evaluate weapon system plans, blueprints, and drawings. Items on the checklist are equipment-oriented and are evaluated against established HE design principles, guidelines, and standards and ranked on a 3-point scale (acceptable, marginal, unsatisfactory).	Planning, Design, Procedures, Error Probability.	Amer. Inst. for Research	211
Equipment Evaluation Guide (EEG)	The EEG is a set of evaluation guides devised for use in prototype special weapon systems. It takes the form of a list of 500 points to look for when assessing various equipment items. When assessing, the analyst compares the prototype equipment with the criteria specified in the guide.	Evaluation	Military	222
Performance Observation Record Form (PORF)	This is an observational record form used for functional evaluation of a prototype system. Operations are observed primarily to identify errors and error-likely situations. Operational procedures are prelisted for the observer, who notes deviations in procedures and problem areas related to equipment operation.	Evaluation	Amer. Inst. for Research	23

Table VI. Summary Descriptions, Reported Uses and Principal Proponent(s) of Major Non-Quantitative Techniques to Describe Human/System Performance (continued)

Techniques	Summary Description	Reported Uses	Proponents	Refs.
Performance Factor Form (PFF)	The Performance Factor Form is a record form that lists performance dimensions identified in the system and the implications of these factors for training.	Training	Amer. Inst. for Research	23
Task Anal. Format for Error Ident.	This is a record and report form showing the equipment and the tasks involved in its operation and the identification of potential operator errors. It also contains suggestions for equipment design and/or procedures to mitigate error possibility.	Design, Procedures, Error Probability.	Amer. Inst. for Research	23
Link Analysis	A Link Analysis is a diagrammatic representation of the frequency of visual, auditory, and control links and their interrelationship between man and man, man and machine, and machine and machine. Analysis of such a diagram provides information useful in the arrangement of workplaces. The primary data obtained in the analysis is "frequency" and "importance" of links, the former being determined objectively and the latter subjectively.	Layout, Procedures.	Military Industry	45, 75, 94

Table VI. Summary Descriptions, Reported Uses and Principal Proponent(s) of Major Non-Quantitative Techniques to Describe Human/System Performance (continued)

Techniques	Summary Description	Reported Uses	Proponents	Refs.
Team Activity Chart	The Team Activity Chart is a graphical-tabular representation of tasks and operators assigned to them along a time-scale, which shows time-sharing among tasks. Analysis of time data has been used for task allocation, design of procedures, and manning.	Allocation, Manning, Procedures.	Amer. Inst. for Research	23
Multiple Process Chart	This is a graphical-tabular representation of tasks being performed simultaneously by several operators and their relationship in time. The technique is used primarily by methods engineers for routine industrial tasks although it has also been used on military systems (aircraft) to analyze activities of pilots and co-pilots during various segments of flight. This family of charts includes multi-man and machine process time charts, gang process charts, and simo-charts.	Layout, Procedures, Safety.	Methods Engineers, Military. Industry.	93
Man-Machine Chart	A man-machine chart is a graphical-tabular representation of motor tasks performed by an operator, showing their relationship in time and the time that the machine is in operation and being used or is idle. Related to the family of man-machine charts is the	Selection, Design, Procedures.	Methods Engineers, Military, Industry.	83, 153

Table VI. Summary Descriptions, Reported Uses and Principal Proponent(s) of Major Non-Quantitative Techniques to Describe Human/System Performance (continued)

Tech-niques	Summary Description	Reported Uses	Proponents	Refs.
Man-Machine Chart (Continued)	man-machine operation time chart and the man-machine process time chart. The forr focuses on the man operation, the latter includes more detail of the machine operation.			
Information-Decision Action Chart (IDA)	The IDA chart is a symbolic-verbal representation that describes tasks in terms of information-decision-action units. The tasks are sequenced vertically and their relationship in time is shown against a time line that runs from top to bottom. A scenario appears on the chart which is number coded to the symbol and provides verbal descriptions of what occurs in each unit. The chart may be used to describe the tasks performed by one or more operators and, if the latter, it will show the relationships and time sharing activities occurring between them.	Design, Allocation, Training, Evaluation, Procedures.	HRB-Singer	193
Mission Profile	The Mission Profile is an essential tool used during early stages of system design to determine how functions or requirements will be fulfilled in the mission context. A time scale and environmental factors are important variables depicted in the profile.	Planning, Allocation.	Military	70

Table VI. Summary Descriptions, Reported Uses and Principal Proponent(s) of Major Non-Quantitative Techniques to Describe Human/System Performance (continued)

Techniques	Summary Description	Reported Uses	Proponents	Refs.
Position Description	The position description (sometimes called a job description) is a record of all the facts that describe the content of the position. This description includes job operations, duties and tasks, equipment and material used, working conditions, time estimates of performance and statements of qualities or abilities that an operator must possess to perform the job in a satisfactory manner.	Manning, Planning, Training, Procedures.	Military	106
Physical Demands Form	This form is used as an aid in collecting and recording facts about a job to be performed. Basically, it serves to identify and analyze what the task calls for in the way of physical activity and the environmental or working conditions under which the task will be performed. Derivatives of this form have been used in personnel subsystem test and evaluation.	Selection, Training, Evaluation.	Government, Industry, Dunlap and Associates, Inc.	265, 278, 521
Job Psychograph	A job psychograph is a list of mental traits required for a job, rated on a five-point scale to designate the extent to which they are necessary for satisfactory performance. This kind of graph shows relative differences	Selection, Prediction, Job Specification.	Industry	265, 278

Table VI. Summary Descriptions, Reported Uses and Principal Proponent(s) of Major Non-Quantitative Techniques to Describe Human/System Performance (continued)

Techniques	Summary Description	Reported Uses	Proponents	Refs.
Job Psychograph (Continued)	among the traits being rated; it does not show differences between jobs. It is a form of job specification, i.e., the qualities a worker must possess to do the job in a satisfactory manner.			
Worker Characteristics Form	This form, also referred to as the "Occupational Characteristics Checklist," and similar to a "Job Analysis Sheet," is a rating technique used to rate jobs in terms of worker qualifications necessary to accomplish them. It is designed to show the differences in degree between jobs by utilizing a 3-point scale to rate each characteristic demanded of the worker to perform the job satisfactorily. Its limitations lie in the excessive amount of time required to complete it and in the rating units, which are not always defined accurately, and which are easily misinterpreted by users. This form is used as a data-gathering tool for the preparation of job specifications.	Selection, Prediction, Job Specification.	Government (Dept. of Labor, USES)	265

Table VI. Summary Descriptions, Reported Uses and Principal Proponent(s) of Major Non-Quantitative Techniques to Describe Human/System Performance (continued)

Techniques	Summary Description	Reported Uses	Proponents	Refs.
Job Description	Job descriptions will vary in detail depending upon the needs of the company. However, most descriptions will contain sufficient information to identify a job by describing its scope, purpose, and content and will contain a detailed description of the work to be performed to cover the "what," "how," and "why" of the job.	Job Rating, Job Classification, Training, Evaluation.	Industry, Government, Military	265, 278
Systems Analysis and Integration Model (SAIM)	SAIM is a descriptive system model which provides an integrated overview of the elements that contribute to mission success. Its key features include: 1) a generalized scheme for classifying weapon system elements, including mechanisms, men, and facilities; 2) a treatment of weapon system elements that is "black box" (input-output) in nature and that is modular (building block) in form, thereby permitting wide latitude in the combination of these elements; 3) a diagrammatic matrix format for arranging and showing interconnections between system elements; 4) use of both qualitative and quantitative means for describing system element interactions; and 5) applicability at any system level. (NOTE: Although the system is adequately described in the literature, this review has failed to uncover any reports of its application in system design and development.)	Planning, Evaluation, Management Control.	Air Force	60, 173

Table VI. Summary Descriptions, Reported Uses and Principal Proponent(s) of Major Non-Quantitative Techniques to Describe Human/System Performance (continued)

Techniques	Summary Description	Reported Uses	Proponents	Refs.
Function Flow Diagram	One of a family of flow diagrams which depicts the sequence, duration, and time relationships of the functions occurring in the mission cycle, the function flow diagram is used early in the acquisition phase to facilitate analysis of operational, maintenance, or support functions identified from the analysis of system requirements as being necessary to accomplish system mission objectives.	Allocation, Procedures Design.	Military, Government, Industry.	56, 70

terms of the scientific method (for example, possessing a commitment to rigorious and yet parsimonious study of the problem, conducting the study as planned, and controlling the quality and interpretation of the information), and the careful design of the test situation (so as to identify clearly the variables to be measured and those to be manipulated or otherwise controlled and the conditions, equipment, and procedures of the test).[18] Planning of studies of human performance in systems contexts requires also the careful analyses and explicit statement of the relationship between the human performance of interest and the system performance so as to justify the selection and execution of the study, to communicate with other specialists engaged in the design, development, and/or the operation of the system, and, ultimately, to benefit and/or assure demonstrably the desired system performance.[19] In addition, designing and/or taking best advantage of test situations during the development of the system implies a thorough understanding of the system development process and the needs for timely, sometimes crucial, information concerning human performance.[20]

b. Techniques for Collecting Information

The behavioral literature contains many references to and techniques for the collection of data in empirical situations. The techniques useful in the empirical situation are variations of the basic method of science: controlled observation. Observation may be direct, as when the human observer is physically and temporally at the test locale, or indirect. The indirect observer often uses interviews to establish information. He can also read reports. Observation may involve the participation of the experimenter, test administrator, or test specialist(s) or it may not.

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[18] The design and planning of tests and studies of human performance is discussed in 13, 95, 96, 109, 118, 121, 124, 127, 142, 158, 160, 179, 188, 189, 190, 192, 197, 287, 288, 292, 293, 296, 298, 304, 384.

[19] Relating human performance to system effectiveness is addressed variously in 2, 9, 28, 32, 35, 36, 65, 136, 145, 194, 195, 315, 320, 394, 403, 431, 442.

[20] see 18, 23, 29, 30, 32, 41, 47, 49, 53, 54, 58, 64, 65, 70, 76, 130, 131, 164, 170, 359, 394, 395, 404, 405, 408, 410, 411, 412, 416, 418, 420, 422, 423, 427, 443.

The behavioral science literature concerned with the collection of human performance information contains techniques for instrumenting, structuring, or formatting the available information. Techniques, such as checklists and rating scales, are designed to structure both the acquisition and the deposition of relevant information and to facilitate the task of information processing beyond the collection stage. Where criterion information is available, these instruments serve also as evaluative instruments providing for the selection and recording of valued-data points by the observer/evaluator. A large body of literature has been developed on the use of structured observation forms and the design of such instruments for the best possible validity and reliability. Table VII contains descriptions of the principal techniques appearing in the behavioral science literature and useful for collecting information in the empirical situation.

Most of the direct observational techniques (e.g., interviews, rating scales, checklists, critical incidents, time and motion practices, performance tests) have long histories of use in the description and analysis of human behavior. Several of the indirect techniques also have been used extensively in the measurement of human behavior, both in the laboratory setting (e.g., response timers, pen recorders, questionnaires), and in the more applied field settings (e.g., paper-pencil surveys, rating scales, questionnaires, paper-pencil tests). There are signs that some newer practices, such as video recording, the use of CRT remote displays, and the use of computers to record and analyze data on a real-time basis are and will become increasingly useful. It is not uncommon to encounter discussions concerning automated laboratories in which the stimulus program, data recording, and data analysis are all handled by a computer. This study reviewed several such laboratories. All that is required of the human subject is that he appear and follow the instructions generated by the computer. The experimenter need not even be present, although he often is. There definitely appears to be a trend toward some form of automation in experimental laboratory settings and, in fact, even in field settings, e.g., the integrated test course for the measurement of combat effectiveness being built for the U.S. Army Quartermaster Corps. This outdoor course, which is capable of all-weather operation, will measure human performance via remote automatic sensors which are linked to a central computer which records and analyzes subject responses (309).

c. <u>Techniques for Reducing and Analyzing Information</u>

Data reduction usually follows data collection and is commonplace in empirical assessments of human performance. The reduction step is one of summarizing, making the information manageable and amenable to additional analyses. The result of this step is typically a narrative summary or a numerical expression summarizing the counting of events or other measures of human performance. Quantified summaries usually take

Table VII. Summary Description of Major Quantitative Techniques for Gathering Empirical Information Concerning Human Performance

Technique	Description	Reference(s)
Electro-Mechanical Data Recording Devices Audio Recorders, Video Recorders, Digital Recorders, Analog Recorders, On-Line Computer, Cameras	The family of information gathering techniques represented by electro-mechanical devices is classified under indirect observation, i.e., the device is interposed between the events to be recorded and the observer. All of these devices are capable of making permanent records of the events which occurred. These records can then be analyzed after the actual data collection has been accomplished. In addition, a major advantage of the use of these techniques is that they provide dynamic information which can be reviewed as often as necessary to provide a thorough analysis. In the case of on-line computer recording of dynamic data, it is possible for the data to be analyzed in real or near real time if desirable. These techniques also provide a high degree of objectivity in data recording which is lacking in some of the other techniques reviewed. However, objective recording does not guarantee objective data categorization and evaluation.	1, 295, 299, 304, 309, 325, 330, 332, 334, 336, 337, 341, 347, 354, 356, 362, 425
Performance Proficiency Tests	Performance tests are based upon the same rationale as paper and pencil tests except that they measure performance in terms of overt behavior rather than cognitive behavior. Often, this type of test is referred to as a proficiency test since it can be utilized to measure the proficiency with which individuals, groups, and organizations can perform certain specified tasks. Performance tests are generally designed to sample units of behavior which are important in terms of achieving criterion performance. In terms of data analysis, performance tests can be analyzed in virtually the same manner as paper and	217, 220, 278, 289, 292, 304, 309, 318, 324, 325, 332, 334, 341, 344, 346, 347, 350, 354, 360, 361, 365, 366, 369, 371, 372, 375, 380, 382, 393, 388, 389, 391, 394,

Table VII. Summary Description of Major Quantitative Techniques for Gathering Empirical Information Concerning Human Performance (continued)

Technique	Description	Reference(s)
Performance Proficiency Tests (continued)	pencil tests. They can be subjected to the same reliability and validity checks as paper and pencil tests. Performance tests have been used in industry and the military and have proven to be useful in practical measurement situations.	399, 425, 431
Paper and Pencil Tests	Paper and pencil test instruments are quite similar in concept and construction to questionnaires. Tests are forms of questionnaires in that they require the subject to respond to questions provided on the form. The primary difference between tests and questionnaires is that tests are designed to measure cognitive abilities while questionnaires are concerned more with variables such as attitudes which are not criterion oriented. A test implies the use of a criterion against which the performance of individuals, groups, or systems is compared to yield an evaluation. A test purports to measure the amount of some aptitude, e.g., mechanical aptitude or ability, i.e., arithmetic, possessed by an individual. Thus, tests are considered as tools for the measurement and evaluation of human performance.	217, 220, 265, 278, 292, 304, 343, 344, 348, 349, 350, 351, 353, 357, 359, 363, 364, 370, 373, 384, 387, 390
Paper and Pencil Questionnaires, Surveys, Inventories	Paper and pencil questionnaires, surveys, inventories, and the like are used extensively in gathering descriptive and evaluative information concerning human performance, particularly cognitive performance. Essentially, these techniques provide a means to obtain structured, standardized observations of performance, opinions, attitudes, interests, abilities, etc. Questionnaires are used particularly often in the measurement of opinions and attitudes concerning a wide array of variables. These self-report techniques serve as	217, 220, 254, 265, 278, 292, 302, 343, 344, 350, 352, 353, 355, 386, 430

Table VII. Summary Description of Major Quantitative Techniques for Gathering Empirical Information Concerning Human Performance (continued)

Technique	Description	Reference(s)
Paper and Pencil Questionnaires, Surveys, Inventories (continued)	a standardized interface between the subject and the observer, i.e., in many cases, a questionnaire can be considered as a highly structured interview without the opportunity of face-to-face interaction. Questionnaire techniques have been used in many theoretical and applied data collection situations. Sophisticated analyses of questionnaire data have yielded many of the constructs, i.e., inferred variables which are utilized in the behavioral sciences, e.g., personality traits, attitudinal dimensions, etc. Generally speaking, well constructed questionnaires have proven to be very useful in behavioral descriptions.	
Interview	The interview is probably one of the oldest and most basic forms of data gathering known. There are two basic forms, i.e., structured and unstructured. In the structured interview, the interviewer requests information of a specific set of items which are organized before the interview. In the unstructured interview, the people in the interview may discuss a variety of topics which were not systematically organized before the interview. While the validity of the interview as a systematic means of collecting data has been questioned, it appears that the technique is still quite useful for eliciting the personal opinions and feelings of individuals regarding topics of interest. It seems particularly useful in conjunction with some of the more objective techniques such as checklists and rating scales. An interview provides an important dimension to data collection, that of face-to-face	212, 213, 219, 222, 227, 241, 244, 247, 248, 256, 257, 259, 262, 266, 267, 268

Table VII. Summary Description of Major Quantitative Techniques for Gathering Empirical Information Concerning Human Performance (continued)

Technique	Description	Reference(s)
Interview (continued)	interaction with the subject which is lacking in most other data collection methods.	
Critical Incident	This technique consists of a set of procedures for collecting direct observations of human behavior so as to facilitate their usefulness in solving practical problems. Critical incidents are human activities which appear to have a special significance which discriminates them from normal activities. This technique has a relatively long history in the Air Force. It has been used in several studies of the reasons for man/machine system failures of various kinds, and to study combat leadership performance in the Army. Generally speaking, the critical incident technique has been used to record relatively extreme forms of performance. It appears that form of this technique is often used during Category II esting of AF systems. Often, a variant of the technique will be used to record man/machine malfunctions or deviations from some predetermined SOP. Thus, when an operator is observed to deviate from the procedure which he is supposed to be following, such an action may be regarded as a critical incident. The technique as presently used requires relatively simple judgments from the observer, but these are subject to all the unreliability of subjective perception. The accuracy and objectivity of these depends upon the precision with which the observed behavioral characteristic has been defined and the ability	200, 223, 225, 226, 228, 230, 231, 232, 233, 237, 277, 284, 286

Table VII. Summary Description of Major Quantitative Techniques for Gathering Empirical Information Concerning Human Performance (continued)

Technique	Description	Reference(s)
Critical Incident (continued)	of the observer to interpret this definition relative to the incident observed. The reduction and analysis of the data resulting from the critical incidents technique summarizes the data so as to make it useful for practical purposes. There are three steps in the data analysis: a) choice of a frame of reference for data classification; b) category formulation; and c) determination of the appropriate level of generality for reporting the data. These steps are not easy to perform, and in cases such as category formulation, a good deal of insight experience and judgment is required. There are no simple rules available for generating categories and the utility and quality of the final product are quite dependent on the skill and sophistication of the formulator. In short, the data reduction task necessary in using the critical incident technique has some skill requirements associated with it.	
Rating Scales	The use of rating scales of various types for recording information about human performance has a long history. The primary function of the rating scale is to systematize and structure the collection of data. It makes use of a series of descriptive behavior categories to which values have been assigned by some process. The categories are then used to describe human behavior and thereby evaluate it. There are many variations on the basic rating model, e.g., Likert scales, Thurstone scales, graphic	201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 214, 215, 216, 218, 219, 235, 238, 240, 249, 251, 252, 253, 260, 261, 269, 273, 274,

Table VII. Summary Description of Major Quantitative Techniques for Gathering Empirical Information Concerning Human Performance (continued)

Technique	Description	Reference(s)
Rating Scales (continued)	scales, adjectival scales, paired comparison, but all of these employ pre-structured behavior categories into which observed behavior is classified. Rating scales have been used extensively in most areas of basic and applied psychology.	276, 280, 281, 282
Checklists	There are two basic types of checklists. Both are made up of a series of descriptive categories which are used in categorizing observed behavior. Weighted checklists utilize pre-assigned scale values for the descriptive categories while unweighted checklists do not. With the former type, a scoring system is built into the instrument while with the latter, evaluations of the resulting data are made after data collection. The checklist is attractive because it is easy to use. The observer does not rate behavior, he merely makes a yes/no decision as to whether a particular category applies. The checklist approach to data collection has been used extensively in many applied settings. Its primary use has been for performance appraisal in industry, educational institutions, and the military. It has also been used a great deal in human engineering design evaluation.	204, 211, 224, 226, 242, 244, 246, 251, 258, 270, 271, 272, 279, 285

statistical forms and refer to the trends or tendencies in the information and/or variations within it.[21] Common statistical forms are measures of central tendency (such as the mean median mode), measures of variability (average and standard deviation, range of variation, etc.), percentages, proportions, percentiles and frequency distributions.

The behavioral literature contains much discussion on the related topics of validity and reliability of observations and measures concerning human performance. Validity refers to the utility of a measure or observation for some purpose: the degree to which the observation corresponds with the need for it. Behavioral studies generally illustrate four types of validity: content, concurrent, predictive, and construct. Content validity is a logical validity based upon the opinions of qualified people that measures of human performance adequately sample the performance on which information is required for evaluation. Concurrent and predictive validities are statistical: the degree of agreement of the measure and its purpose are determined by correlational procedures. Construct validity is a logical validity in which estimates are made of the degree to which a measure or observation of human performance reflects some underlying human ability or function. The concept of the reliability of measurement, differentiated from the reliability of equipment operation (probability of operation at a given time) is estimated by the statistical agreement among repeated observations and there are a number of statistical expressions referring to the absolute and relative reliability characteristics of the measures.

Reliability and validity are related concepts in the striving to obtain useful information concerning human performance. Increasing the reliability of the information often involves acquiring measures more closely resembling each other and, therefore, possibly more close to the "truth" about human performance. However, a set of observations might be highly consistent but not true. On the other hand, highly valid or useful measures necessarily involve high reliability or consistency. A number of excellent references for both concepts, reliability and validity, are to be found in the behavioral literature, e.g., Lindquist (319).

Various statistical techniques have been developed for deriving meaning from the summarized observations of human performance. They generally fall into two types, parametric and nonparametric, depending upon the assumptions which can be made concerning the types of measures and certain of their statistical characteristics. Several techniques for determining

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[21] References for this section include, for example, 288, 294, 297, 298, 300, 301, 302, 303, 306, 307, 310, 311, 313, 317, 318, 319, 323, 329, 328, 331, 333, 335, 338, 339, 340, 350, 355, 366, 370, 373, 385, 386, 387, 390.

the degree of association and the statistical significance of differences between sets of information, e.g., expected human performance and observed performance, have been developed and are currently in use. They are described briefly in Table VIII.

D. Summary and Overview

The phenomena of human performances occur without benefit of system designer or behavioral scientist, but the data of man-machine performance are the joint product of analysts and observers and the phenomena--coupled with specially contrived data-generating situations and techniques. This chapter has reviewed the repertoire of the behavioral sciences for generating data from available information[22] and for deriving meaning from them.

For the most part, what was seen in the state of the art as a result of this review was a variety of familiar techniques and approaches in the assessment of human performance. The principal methods for deriving information concerning human performance are variations of logical assumption, indirect human observation (e.g., interviewing), and direct human observation. The principal methods for deriving meaning from the information rely upon human reasoning and involve comparison with previous information. Placing a value upon the discovered facts requires judgment by and, often, consensus among the users of the evaluated information.

With reference to the assessment process, the literature of the behavioral sciences contains numerous methodological studies, guidelines and handbooks which provide: (1) quantitative and non-quantitative heuristic techniques for conceptualizing about human performance in the context of the system environment and activity, (2) techniques for structuring and controlling observation and recording in empirical assessment situations, and (3) quantitative (statistical and mathematical) techniques for examining the meaning of data against expectations and needs.

Many of the techniques noted in this chapter have long histories of usefulness in the pursuit of evaluative information concerning human performance. This is the case for rating scales, questionnaires, and some

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[22] See Coombs (298) for an excellent overview of "information" and "data" in behavioral science research.

Table VIII. Summary of Quantitative Techniques for Reducing and Analyzing Empirical Information Concerning Human Performance

CONDITIONS OF ANALYSIS		TYPE OF ANALYSIS: PARAMETRIC	References	NONPARAMETRIC	References
SIGNIFICANCE OF DIFFERENCES	Two Sets of Measures CORRELATED	t Test (correlated measures)	294, 310,	McNemar test (for significance of changes) Sign test Wilcoxon matched-pairs signed-ranks test Walsh test Randomization test for matched pairs	301, 333, 335, 338,
	UNCORRELATED	t Test (uncorrelated measures) Critical Ratio (CR) F Test (analysis of variance)	310,	Fisher exact probability test χ^2 test (two independent samples) Median test Mann-Whitney U-test Kolmogorov-Smirnov two-sample test Wald-Wolfowitz runs test Moses test of extreme reactions Randomization test for two independent samples	301, 333, 335, 338,
	>Two Sets of Measures CORRELATED	F Test Analysis of variance (related measures designs) Analysis of covariance (related measures designs	297, 301, 310, 319, 331, 340,	Cochran Q test Friedman two-way analysis of variance	301, 307, 333, 335, 339,
	UNCORRELATED	F Test Analysis of variance (unrelated measures designs) Analysis of covariance (unrelated measures designs)	297, 301, 319, 331, 340,	χ^2 test (k independent samples) Extension of median test Kruskal-Wallis one-way analysis of variance	301, 317, 333, 335, 339,
MEASURES OF ASSOCIATION AND PREDICTION	TWO OR MORE SETS OF MEASURES	Product moment correlation (r) Biserial correlation (r_b) Point biserial correlation (r_{pb}) Phi coefficient (ϕ) Tetrachoric correlation (r_t) Correlation ratio (η) Partial correlation Multiple correlation (R) Coefficient of determination Multivariate analysis Factor analysis	297, 301, 310, 340,	Kendall rank correlation (τ) Kendall partial rank correlation Kendall coefficient of concordance (W) Contingency coefficient (C) χ^2 Spearman rank correlation (r_s)	301, 313, 333, 335,

parametric statistical techniques.

Noticeable among the relatively novel and promising approaches are various techniques of "modern" mathematics, (e.g., graph theory, game theory), the use of computer-based "automated laboratories", and the treatment of data by nonparametric statistical analysis.

It was noted that the major advantage of the newer, non-classical mathematical approaches is that they can aid the behavioral scientist discover and explore aspects of human performance and conceive of the variables, range of variation and covariation in terms testable by the classical mathematical techniques. In addition to the use of heuristic mathematical procedures, it was noted that non-quantitative heuristic procedures are available and are in general use. It would seem that a promising direction for improving the tools of early system design is the combination of the diagrammatic-verbal and the mathematical heuristics.

The use of automated laboratories is fairly widespread at this time. These are computer-based stimulus presentation and response recording, scoring systems. This development probably represents a modern version of the "brass-instrument" experimentation in the behavioral sciences, but the promise of automated and reliable data collection as well as the handling and on-line reduction of large amounts of information is exciting. The possibility of new efficiencies in the matter of deciding, through computer-based sequential sampling techniques, when to stop collecting data is also promising in this context.

The review of practices in data reduction indicate the availability and potential usefulness of nonparametric statistical techniques for analyzing measures of human performance. The techniques are generally similar to parametric techniques in power and use and are practicable in system test and evaluation programs. Moreover, these techniques are, in many cases, more appropriate than parametric techniques for treating the data of human performance.

IV

REVIEW OF ASSESSMENT PRACTICES IN SELECTED AIR FORCE SYSTEMS

A. Introduction to the Review of Systems

This section presents a discussion and tabulation of practices, as reviewed during this study, for assessing human performance in four major types of man-machine systems. The four types of systems are: space, aeronautical, missile, and electronic, these designations deriving principally from the name of the division within Air Force Systems Command which has had cognisance over the development of the system or subsystem. The focus of this section is on a review of methods and techniques rather than the findings of the assessment programs. The purpose here is principally descriptive rather than evaluative, so that, beyond an organization of the information into format convenient for tabulation and exposition, no attempt is made to compare methods or techniques or to derive an evaluative schema. This information is intended also to be illustrative rather than definitive. Clearly, it does not represent all the programs that have been carried out to date, but it does satisfy the general purpose of this review, namely, the illustration of the ways in which human performance is known and assessed in the context of the typical military system.

This section is subdivided into five sub-sections. Four of these present findings concerning practices in different types of systems. The last subsection summarizes the information and categorizes the techniques illustrated in the various test reports and programs. A listing of reports available and used during this review has been organized by type of system and is presented in the Reference section of this report.

B. Practices for Assessing Human Performance in Space Systems

1. Human Performance in Space Systems

Space systems are designed to function principally in the extraterrestrial environment although many activities in the typical mission take place on the ground. Humans function generally in these systems as vehicle controllers and passengers, ground controllers and assistants to the vehicle pilot(s), and/or as decision-makers and participants in the checkout, launch, and recovery of the space vehicle. Some space vehicles are unmanned: their purpose is to extend the capacities of the human on the ground to acquire information, to communicate, etc. A variety of human performances must be described and assessed in the typical system development program. Highlighted among the aspects of flight performance (interactions within the focal P.E.A. unit) that require description and

evaluation are performance as a function of weightlessness, life-support facilities, specialized displays and controls and crew composition. With respect to the checkout and launch of the space vehicle and its ground support equipment, heavy emphasis is being given to the study of automation--the support of the checkout crew by computer and other equipment. Ongoing studies in this area concern human decision-making and both the need for and acceptance of computer support by the maintenance and operational personnel. Human communication with the computer is also a subject of investigation with studies concentrating largely upon an information system for man-computer symbiosis.

2. Summary and Description of Information Reviewed

The foregoing discussion limned those aspects of human performance which are currently being emphasized in space programs. This section summarizes the systems, types of reports, etc., which concerned the assessment of such performances and which were available during this study. Table IX summarizes and describes this information.

Assessessment activities in four space systems, subsystems, or contexts were reviewed: the GEMINI B, MANNED ORBITING LABORATORY (MOL), APOLLO, and SATELLITE CONTROL FACILITY. Table IX indicates that the system document available for review described activities in all phases except conceptual. We reviewed documents describing activities during the conceptual phase. The reports tended to concentrate either upon the activities which take place during the early system development phases or proficiency measurement during actual system operations. The techniques described were oriented toward both laboratory and field testing of subsystems, equipments, and man-machine interfaces.

The information which was available for the space systems was acquired during conferences with SPO and contractor personnel concerned with the specific system or subsystem and from reports presenting test plans, results, or general descriptions of the system life cycle. Table IX indicates that conferances were held for all systems covered, and that there were a number of test planning and general system documents available. The principal source of the methodological information reported for the space systems was test planning documentation.

Information available for the space systems/subsystems varied in terms of the focus or objectives of the test planning or evaluation. In many cases, it was clear that human performance per se was not measured, e.g., in the static review of human engineering characteristics of equipment design. In these cases, human performance was assumed to be related to the conditions under which it was observed or to the products and processes that supported performance. Performance was being investigated as a

Table IX. Summary and Description of Information Reviewed Concerning the Assessment of Human Performance in Space Systems

System/Subsystem Nomenclature	General Description	System Phase at Time of Review				Sources of Information				Reported Focus of Information				
							Document							
		C	D	A	O	Conference	Test Plans	Test Results	General Descrip.	Equip. Design	Train-ing	Operat. Proced.	Personnel Selection	Environ. Factors
GEMINI-B	Research and development program leading to series of two-man orbiting flights			X		X		X		X		X		X
SATELLITE CONTROL FACILITY	Global communication and control system for tracking, interrogating and controlling manned and unmanned space vehicles				X	X	X	X		X	X	X	X	X
MANNED ORBITING LABORATORY	Experimental space flight series to measure man's capabilities in performing a variety of tasks in space		X			X	X		X	X		X		X
APOLLO	Research and development program leading to multi-man landing and exploration on moon		X			X	X		X	X		X		

C: Conceptual Phase; D: Definition Phase; A: Acquisition Phase; O: Operational Phase

function of design, training, operating procedures, personnel skills, and environmental factors. The frequency with which this was done is contained in Table X. Many reports, e.g., test plans, contained more than one reported focus.

In general, the available information indicates that human performance in space systems was being evaluated principally as a function of equipment design, operating procedures and environmental factors.

3. Detailed Findings Concerning Performance Assessment Practices in Space Systems

The preceding section has provided the framework of the information available concerning the assessment of human performance in space systems. This section summarizes the available details concerning assessment techniques. This information is contained in Table X. The table indicates: a) the system nomenclature, b) the focus upon human performance, e.g., as a function of design, represented by the techniques listed, c) the characteristics of the assessment situation, i.e., static or dynamic evaluations, d) the types of techniques used for data collection and data reduction/evaluation, and e) the specific system documents from which the information was derived and the time period within which they were published.

A variety of techniques are used in space systems or contexts for evaluating human performance. Information concerning systems in early stages of development indicated the usefulness of paper and pencil techniques, such as task equipment analyses, time-line, and flow diagrams for collecting and examining information. The early introduction into the development cycle of high fidelity simulation in which man performed was characteristic of the programs reviewed. Simulation was accompanied by structured and remoted observation forms and apparatus, e.g., video recording. Data reduction/evaluation techniques could be divided into quantitative and qualitative techniques. Quantitative techniques ranged from simple analyses using frequency counts to sophisticated treatments involving statistical comparisons and tests for significance of differences and relationships. In the qualitative category, the data reduction technique most often used was the narrative summary, i.e., verbal descriptive discussions, paragraphs, or tables.

C. Practices for Assessing Human Performance in Aeronautical Systems

1. Human Performance in Aeronautical Systems

Aeronautical systems typically require that humans control and direct aircraft and associated equipment subsystems through various phases of powered flight and take-off/landing during a system mission. The aeronautical systems also include ground support personnel and equipment.

Table X. Detailed Summary of Human Performance Assessment Practices in Space Systems

System Nomenclature	Human Performance Focus/Use					Assess. Situation		Assessment Practices		Ref. and Time Period
	EQ.	TR.	PS.	TO.	EN.	ST.	DY.	Data Collection	Data Reduction/Eval.	
GEMINI-B	x			x	x		x	Direct observation	Descriptive statistics	458, 461 (1962-1964)
	x			x	x		x	Stopwatch	Descriptive statistics	
	x						x	Anthropom. measures	Descriptive statistics	
	x			x			x	Simulation	Comparative statistics	
	x			x			x	Interview	Narrative summary	
	x			x			x	Automatic data record.	Comparative statistics	
SATELLITE CONTROL FACILITY	x	x		x	x		x	Interview	Narrative summary	448, 450, 451, 453, 454, 455, 456, 459, 460 (1964)
	x	x	x	x	x		x	Direct observation	Descriptive statistics	
		x		x			x	Performance checklist	Descriptive statistics	
		x		x			x	Rating scales	Descriptive statistics	
		x		x			x	Voice recorder	Descriptive statistics	
		x		x				Indirect observation	Descriptive statistics	
MANNED ORBITING LABORATORY (MOL)	x			x	x	x		Task analysis	Diagrammatic	447 (1965)
	x			x	x	x		Interview	Narrative	
	x	x		x	x		x	Simulation	Comparative statistics	
	x	x		x	x		x	Automatic data record.	Comparative statistics	
		x		x			x	Voice recorder	Descriptive statistics	
		x		x			x	Indirect observation	Narrative summary	
	x			x	x	x		Time line analysis	Diagrammatic	
APOLLO	x			x	x	x		Task analysis	Diagrammatic	452, 457 (1964-1965)
	x			x	x	x		Interview	Narrative summary	

EQ. Equipment Design TR. Training PS. Personnel Selection TO. Operating Procedures
EN. Environmental Factors ST. Static DY. Dynamic

The assessment of pilot performance often involves attention to his physical accommodation, his control behavior, and his survival. The performance of ground personnel consists largely of maintenance activities, and the evaluative focus is on the safety, reliability, and speed of their performance. Techniques and opportunities for developing, measuring, and assessing human performance have been developed over a period of many years and have benefitted from a variety of techniques developed (e.g., flight simulators) and programs conducted (e.g., the evaluation of pilot proficiency) during and since the Aviation Psychology Program of World War II.

2. Summary and Description of Information Reviewed

The foregoing discussion indicated some of the emphases in the evaluation of the performance of pilots and ground support personnel in aeronautical systems. This section summarizes the systems, programs, and reports which concerned the assessment of such performance and which were available during this review. Table XI summarizes and describes this information.

Assessmen[illegible]ies in eleven aeronautical systems, subsystems or contexts were revi[illegible] [illegible]he eleven systems or subsystems included bomber, cargo, and fighter aircraft, and one helicopter system. Flight simulators for the B-47, B-58, and the F-111 aircraft and the Sikorsky helicopter simulator were also reviewed. The documents available for review concerned systems or subsystems in the acquisition and operational phases. No documents referred to these or other man-machine interactions in earlier phases of development. The techniques described, therefore, were oriented toward assessment situations in which the human component could be seen interacting with the real or closely simulated system environment. The principal sources for information concerning the use of these techniques were documents containing test plans or test results.

Evaluative activities in aeronautical systems focussed on performance in a variety of interactions involving personnel-environment-activity. Equipment design, training, and procedural parameters were emphasized.

3. Detailed Findings Concerning Performance Assessment Practices in Aeronautical Systems

The preceding section has described the information on which this section is based. Table XII presents details concerning the assessment techniques represented in the available information. The format of the presentation is the same as that used for summarizing methodological information for the space systems.

The tabled information suggests a variety of used and useful data collection techniques, typical among which are checklists, questionnaires, rating scales, interviews, and simulators which use automatic data recording.

Table XI. Summary and Description of Information Reviewed Concerning the Assessment of Human Performance in Aeronautical Systems

System/Subsystem Nomenclature	General Description	System Phase at Time of Review				Sources of Information	Document			Reported Focus of Information				
		C	D	A	O	Conference	Test Plans	Test Results	General Descrip.	Equip. Design	Train-ing	Operat. Proced.	Personnel Selection	Environ. Factors
B-52/GAM-77	Missile Armament System for B-52				X		X	X			X	X		
C-141	Cargo Aircraft			X		X	X	X	X	X	X	X	X	
B-58	Bomber Aircraft			X		X		X	X	X	X	X		
B-25	Bomber Aircraft				X			X			X	X		
B-47	Bomber Aircraft				X	X		X	X	X		X		X
F-5 A/B	Fighter Aircraft			X			X	X		X	X	X	X	X
F-4C	Fighter Aircraft			X		X	X	X		X	X	X	X	X
CH-3C	Helicopter			X			X	X		X		X		X
AN/APQ-24	Navigational and Bombing System for B-52				X		X	X			X			
Flight Simulators: Helicopter, B-47, B-52	Generalized Dynamic Flight Simulators			X		X	X			X	X	X		
F-111 A/B-DORA	Dynamic Operator Response Apparatus F-111 A, B			X		X	X	X		X		X		

C	D	A	O
Conceptual Phase	Definition Phase	Acquisition Phase	Operational Phase

Table XII. Detailed Summary of Human Performance Assessment Practices In Air Force Aeronautical Systems

System Nomenclature	Human Performance Focus/Use					Assess. Situation		Assessment Practices		Ref. and Time Period
	EQ.	TR.	PS.	TO.	EN.	ST.	DY.	Data Collection	Data Reduction/Eval.	
B-52/ GAM-77	x	x					x	Interview	Descriptive statistics	474, 483
		x		x			x	Checklist	Descriptive statistics	489
		x					x	Paper/pencil pre-test	Comparative statistics	(1960-61)
		x					x	Paper/pencil post-test	Comparative statistics	
		x		x			x	Paper/pencil achievement test	Descriptive statistics	
		x					x	Questionnaire	Comparative statistics	
		x		x			x	Simulation	Comparative statistics	
		x		x			x	Crew evaluation questionnaire	Descriptive statistics	
C-141	x				x	x		Anthropom. measures	Descriptive statistics	462, 465,
	x	x		x	x		x	Demonstration	Narrative summary	466, 467,
	x				x	x		Human engineering checklist	Narrative summary	468, 487 (1963-64)
	x						x	Mock-up study	Narrative summary	
	x						x	Simulation	Descriptive statistics	
		x				x		ATC train. question.	Descriptive statistics	
		x					x	Indiv. post-task quest.	Narrative summary	
		x		x			x	Maintenance report	Narrative summary	
		x	x				x	AFSC Form 258-4	Descriptive statistics	
	x		x	x	x		x	System discrep. rpt.	Narrative summary	
	x	x		x	x		x	Post-test interview	Narrative summary	
			x					Direct observation	Narrative summary	

EQ. Equipment Design TR. Training PS. Personnel Selection TO. Operating Procedures
EN. Environmental Factors ST. Static DY. Dynamic

Table XII. **Detailed Summary of Human Performance Assessment Practices In Air Force Aeronautical Systems (continued)**

System Nomenclature	Human Performance Focus/Use					Assess. Situation		Assessment Practices		**Ref. and Time Period**
	EQ.	TR.	PS.	TO.	EN.	ST.	DY.	Data Collection	Data Reduction/Eval.	
B-58	x				x	x		Direct observation	Narrative summary	463, 486 (1960-61)
	x			x	x		x	Time line analysis	Diagrammatic summary	
	x			x	x		x	Interview	Narrative summary	
		x	x			x		Personnel record	Descriptive statistics	
		x	x			x		Questionnaire	Descriptive statistics	
B-25		x		x			x	Checklist	Descriptive statistics	492, 493 (1953-54)
		x		x			x	Direct Observation	Descriptive statistics	
			x	x			x	Rankings	Comparative statistics	
B-47	x			x	x		x	Demonstration	Narrative summary	464 (1952)
					x	x		Anthropom. measures	Descriptive statistics	
	x				x	x		Human engineering checklist	Narrative summary	
	x	x		x	x		x	Direct observation	Narrative summary	
	x					x		Mock-ups	Narrative summary	
	x	x			x	x		Interviews	Narrative summary	
	x				x	x		Questionnaires	Descriptive statistics	
	x			x	x	x		Opinion Surveys	Narrative summary	

EQ. Equipment Design TR. Training PS. Personnel Selection TO. Operating Procedures
EN. Environmental Factors ST. Static DY. Dynamic

Table XII. Detailed Summary of Human Performance Assessment Practices In Air Force Aeronautical Systems (continued)

System Nomenclature	Human Performance Focus/Use					Assess. Situation		Assessment Practices		Ref. and Time Period
	EQ.	TR.	PS.	TO.	EN.	ST.	DY.	Data Collection	Data Reduction/Eval.	
F-5A/B	x	x			x		x	AFFTC checklist A/C	Descriptive statistics	475, 476, 477, 478, 479, 480 (1964)
	x	x			x		x	AFFTC checklist AGE	Descriptive statistics	
	x				x	x		AFFTC pilot opin. surv.	Narrative summary	
	x	x		x	x		x	Task activity form	Descriptive statistics	
	x				x	x		Post-task interv. form	Narrative summary	
	x				x	x		Maint. pers. opin. form	Narrative summary	
	x	x			x		x	Maint. event recd. form	Descriptive statistics	
	x	x		x	x		x	Direct observation	Descriptive statistics	
		x					x	Training stds. checklist	Narrative summary	
			x				x	AFFTC posit. desc. form	Narrative summary	
				x			x	Motion photography	Narrative summary	
			x					Personal backgrd. info.	Descriptive statistics	

EQ. Equipment Design TR. Training PS. Personnel Selection TO. Operating Procedures
EN. Environmental Factors ST. Static DY. Dynamic

Table XII. Detailed Summary of Human Performance Assessment Practices In Air Force Aeronautical Systems (continued)

System Nomenclature	Human Performance Focus/Use					Assess. Situation		Assessment Practices		Ref. and Time Period
	EQ.	TR.	PS.	TO.	EN.	ST.	DY.	Data Collection	Data Reduction/Eval.	
F-4C	x	x		x	x	x	x	Direct observation	Narrative summary	473 (1964)
	x			x	x	x		HE evaluation rec.		
								a) anthropometry		
								b) control/display	Narrative summary	
								c) maintenance	Descriptive statistics	
								d) safety		
								e) work operations		
	x	x		x			x	Photography	Visual analysis	
	x			x			x	Automatic Flt. Proc.	Descriptive statistics	
	x			x			x	Range instrument	Descriptive statistics	
	x			x	x		x	Interview	Narrative summary	
	x			x			x	Debriefing record	Narrative summary	
		x		x			x	Maint. event record	Narrative summary	
		x		x			x	Maint. pers. opin. qu.	Narrative summary	
	x	x				x		Student opin. quest.	Narrative summary	
		x	x	x			x	AFTO(210, 211) fms.	Descriptive statistics	
CH-3C Heli-copter	x			x		x		Task/equip. analysis	Diagrammatic summary	484, 485 (1963)
	x					x		HE checklist	Descriptive statistics	
	x			x			x	Interviews	Narrative summary	
	x			x	x		x	Demonstration	Narrative summary	
	x						x	Mock-ups	Narrative summary	
	x			x		x		Mission analysis	Diagrammatic summary	
	x			x		x		OSD	Diagrammatic summary	

EQ. Equipment Design TR. Training PS. Personnel Selection TO. Operating Procedures
EN. Environmental Factors ST. Static DY. Dynamic

Table XII. Detailed Summary of Human Performance Assessment Practices In Air Force Aeronautical Systems (continued)

System Nomenclature	Human Performance Focus/Use					Assess. Situation		Assessment Practices		Ref. and Time Period
	EQ.	TR.	PS.	TO.	EN.	ST.	DY.	Data Collection	Data Reduction/Eval.	
AN/ APQ-24 Naviga- tional and Bomb- ing system		x		x		x		Subject-matter tests	Comparative statistics	469, 470, 471, 472, 491 (1954)
		x		x		x		Trouble-shooting tests	Comparative statistics	
		x		x			x	Performance tests	Comparative statistics	
		x		x			x	Performance ratings	Comparative statistics	
			x			x		Biographical invent.	Descriptive statistics	
			x			x		Attitude survey	Descriptive statistics	
		x		x			x	Perf. trbl. shoot. test	Descriptive statistics	
		x		x			x	Direct observation	Descriptive statistics	
		x		x				The Tab Test	Comparative statistics	
Flight Simula- tors (Helicop- tor, B-47 B-52)	x	x		x			x	Automatic data rec.	Comparative statistics	482, 488, 494 (1962)
	x			x			x	Adjectival rating sc.	Descriptive statistics	
	x			x			x	Critical incident tech.	Descriptive statistics	
	x	x		x			x	Direct observation	Narrative summary	
F-111A/B DORA	x	x		x			x	Simulation	Comparative statistics	472, 481, 490 (1964-65)
	x			x			x	Automatic data rec.	Comparative statistics	
	x						x	Pilot debriefing	Narrative summary	
	x						x	Interview	Narrative summary	
	x			x			x	Indirect observation	Narrative summary	

EQ. Equipment Design TR. Training PS. Personnel Selection TO. Operating Procedures
EN. Environmental Factors ST Static DY. Dynamic

In addition, collecting information through the use of standard AFLC maintenance and logistics forms yields useful information concerning the type of maintenance activities performed in the field, the time spent in performing them, and the type of personnel participating in the job. The information appears useful in investigating the assignments of Air Force specialists and in verifying the coverage of maintenance subject matter in the training curricula. For the most part, information from these sources is reduced to narrative and/or statistical summaries.

D. Practices for Assessing Human Performance in Missile Systems

1. Human Performance in Missile Systems

The human role in missile systems, particularly ballistic systems, is largely to maintain readiness, monitor, and launch. Modern missile systems are operationally ready to react very quickly and their countdowns are almost completely automated except for procedural, manual, and inter-personnel safeguards against illegitimate and unauthorized launches. The typical activities of the system personnel involve monitoring equipment status, security of the launch and control areas; and training and communicating within the context of the User Command force exercises. Humans work in shelters, silos, or capsules, which are relatively comfortable, and which support life for normal and emergency conditions. The environment is "shirt-sleeve." The human controller does not fly or otherwise move with the weapon vehicle. The emphasis in programs for assessing human performance is upon human vigilance, fault detection and reporting, safety and reliability in maintenance activities, malfunction diagnosis and maintenance dispatching, and man-computer dialogue. For the most part, missile systems rely upon computers to provide continuous monitoring of large amounts of information and to supply console or rack indications of operational and maintenance status.

The following section reviews the assessment of human performance in missile systems. The first part provides an overview of the type of information available and a summary of methodological information. The second part is more detailed and emphasizes specific foci and techniques for data collection and reduction. Specific system reports are also referenced in this part.

2. Summary and Description of Information Reviewed

Information on seven missile systems or related programs was reviewed. All systems were in the acquisition stage at the date of the conference and/or the report. Test plans, test reports, and general system information were gathered for all ballistic missile systems to date. Test and evaluation in missile systems concerned all aspects of personnel subsystem functioning. Table XIII contains a summary of the information available for the missile systems.

Table XIII. Summary and Description of Information Reviewed Concerning the Assessment of Human Performance in Missile Systems

System/Subsystem Nomenclature	General Description	System Phase at Time of Review				Sources of Information				Reported Focus of Information				
							Documents							
		C	D	A	O	Conference	Test Plans	Test Results	General Descrip.	Equip. Design	Training	Operat. Proced.	Personnel Selection	Environ. Factors
THOR WS 315-A	Intermediate range ballistic missile system			X		X	X	X	X	X	X	X	X	X
ATLAS E WS 107A-1	Intercontinental ballistic missile system			X	X	X	X	X	X	X	X	X	X	X
TITAN I WS 107A-2	Intercontinental ballistic missile system			X	X	X	X	X	X	X	X	X	X	X
TITAN II WS 107C	Intercontinental ballistic missile system			X	X	X	X	X	X	X	X	X	X	X
MINUTEMAN WS 133B	Intercontinental ballistic missile system			X		X	X	X	X	X	X	X	X	X
MACE TM-76B	Short-range guided missile			X			X			X	X	X	X	X
PROGRAM 279				X				X		X	X	X	X	X

Conceptual Phase | Definition Phase | Acquisition Phase | Operational Phase

3. Detailed Findings Concerning Performance Assessment Practices in Missile Systems

Table XIV presents detailed information concerning the data collection and reduction/evaluative practices illustrated in missile systems reviewed during this study. It is probably safe to say that human performance assessment in missile systems during the acquisition stage has drawn heavily on the repertoire of the behavioral science methods and that all techniques for securing and deriving meaning from information have been used to date. Ballistic missile test programs at contractor facilities and at the Pacific and Atlantic Missile Ranges include not only the detailed requirement but provide the opportunity for assessing the performance of system personnel in near-operational environments. Systematic data collection situations have been set up for both operational and maintenance activities. Characteristic of field studies in ballistic missile test programs, the system of trained, non-participant observer-evaluators has been developed to a point that sophisticated statistical treatment of the data secured by this system is currently being attempted on the Minuteman program. Computer simulation, using the IBM/Boeing-developed General Purpose System Simulation Model, is being used to examine the effects of various personnel errors and decisions upon missile availability, maintenance scheduling and force posture. Operability, maintainability and reliability are key human factor programs stimulating careful demonstrations under controlled conditions of adequate system operation and maintenance. The test site at Vandenberg Air Force Base has developed a resident Air Force capability to direct and carry out the assessment of human performance. Human performance is assessed actively through Category III testing in the operational phase.

E. Practices for Assessing Human Performance in Electronic Systems

1. Human Performance in Electronic Systems

Most systems in the inventory of the Air Force have electronic components and subsystems. Considering this, it would be difficult to distinguish any single group of systems as "electronic." For purposes of this section, however, those systems under the jurisdiction of the Electronic Systems Division during their development are listed in the category of electronic systems. The human role in these systems is typically to participate in missions variously involving communication, command, control, warning, direction, detection, intelligence, surveillance, data processing and similar activities. The use of such terms suggests that these man-machine systems function to handle information and communications in several forms and for several purposes. From a man-centered point of view, the equipment of the electronic systems serve to extend human capabilities and mitigate human limitations for sensing, processing and acting upon information concerning tactical and other situations of military interest. System personnel typically monitor the displays provided by system

Table XIV. Detailed Summary of Human Performance Assessment Practices in Air Force Missile Systems

System Nomen-clature	Human Performance Focus/Use					Assess. Situation		Assessment Practices		Ref. and Time Period
	EQ.	TR.	PS.	TO.	EN.	ST.	DY.	Data Collection	Data Reduction/Eval.	
MINUTE-	x	x		x		x		Oper. seq. diagram	Diagram/desc. stat.	495, 497,
MAN	x				x	x		HE checklist	Narrative summary	500, 501,
ICBM	x				x	x		Life Supp. checklist	Narrative summary	505, 508,
WS	x			x	x		x	Mock-up	Narrative summary	509, 511,
133B	x	x	x	x	x		x	Simulation	Descriptive statistics	516, 519,
	x	x		x	x	x		Time-line analysis	Graph, narrative sum.	520, 522,
	x	x	x	x	x	x		Form B, C, C1 Anal.	Tabular/ narrative sum.	525, 527,
	x	x		x		x		Fault-tree analysis	Tabular/ narrative sum.	528, 531,
	x			x	x	x		Computer Simulation	Descriptive summary	541, 544,
	x			x	x	x		Maintainability chklst.	Narrative summary	549
	x	x	x	x	x		x	Field observ. & rec.	Quantitative summaries correlational analysis	(1962-65)
THOR								Human Factor Test		521, 523,
IRBM								Schedule System:		524, 526,
WS	x	x	x	x	x		x	Activity desc. checklist	Narrative summary	529, 542
315A	x	x	x	x	x		x	Syst. criteria checklist	Narrative summary	(1959)
			x	x			x	Phys. & mental dem. Checklist/rating scale	Freq. count/des. stat.	
					x		x	Env. desc. checklist and rating scale	Descriptive statistics	
				x			x	Inter. per. perf. chklst.	Time/line-proc. diag.	
	x			x			x	Sim. task chart	Time/line-proc. diag.	
	x					x		Equip. adeq. checklist	Narrative summary	

EQ. Equipment Design TR. Training PS. Personnel Selection TO. Operating Procedures
EN. Environmental Factors ST. Static DY. Dynamic

Table XIV. Detailed Summary of Human Performance Assessment Practices in Air Force Missile Systems (continued)

System Nomen-clature	Human Performance Focus/Use					Assess. Situation		Assessment Practices		Ref. and Time Period
	EQ.	TR.	PS.	TO.	EN.	ST.	DY.	Data Collection	Data Reduction/Eval.	
THOR					x	x		Safety checklist	Narrative summary	
IRBM	x		x			x		Instrumentation record	Diagrams	
WS					x	x		Ambient cond: record	Diagrams	
315A	x	x	x	x	x	x	x	Interview	Narrative summary	
(cont'd.)				x			x	Simulation (role playing)	Narrative summary	
					x	x		Sound level meters	Descriptive statistics	
					x	x		Gas analyzer	Narrative summary	
				x			x	Motion-time pictures	Narrative summary	
							x	Still pictures	Narrative summary	
							x	Tape recorder (sound)	Narrative summary	
	x			x	x	x		Oper. seq. diagrams	Diagrams	
	x							Lab. experimentation	Descriptive statistics	
	x							HE checklist	Tabulations statistics narrative	
	x	x		x				Rating scale (unit prof.)	Descriptive statistics	
	x							Mock-ups	Narrative summary	
ATLAS	x				x	x		HE checklist	Tabulation/narrative	502, 503,
E	x	x	x	x	x		x	Pers. perf. checklist	Tabulation/narrative	506, 507,
ICBM	x	x	x	x	x		x	Post test interviews	Narrative summary	517, 538,
WS				x	x		x	Voice recorders	Narrative summary	540
107A	x			x	x		x	Motion pictures	Narrative summary	(1959-61)
	x			x			x	Stopwatch	Descriptive statistics	

EQ. Equipment Design TR. Training PS. Personnel Selection TO. Operating Procedures
EN. Environmental Factors ST. Static DY. Dynamic

Table XIV. Detailed Summary of Human Performance Assessment Practices in Air Force Missile Systems (continued)

System Nomenclature	Human Performance Focus/Use EQ.	TR.	PS.	TO.	EN.	Assess. Situation ST.	DY.	Assessment Practices: Data Collection	Data Reduction/Eval.	Ref. and Time Period
ATLAS	x	x		x	x		x	Maintainability checklist	Tabulation/narrative	
E	x				x		x	Rating scales in comb.	EDP tabulation of codes	
ICBM										
WS	x	x	x	x	x		x	With dev. diff. rpts.	Narrative, desc. stat.	
107A	x	x	x	x	x			Summary anal. rep.	Narrative summary	
(cont.d)	x	x		x		x		AFTO forms-mal. anal.	Content anal./narr. sum.	
	x	x	x	x	x	x		Task anal. worksheets	Narrative summary	
	x	x	x	x	x	x		Integrated task index	Diagrammatic/time-line	
	x	x	x	x	x	x		Pos. equip. task sum.	Tabular summaries	
	x			x	x	x		Sys. flow diagrams	Diagrams	
TITAN	x	x		x	x			Observer/eval. forms	Narr. desc. stat.	496, 536,
I	x				x			Photographs	Illustrations	537
ICBM	x	x	x	x	x			Interview	Narrative summary	(1958-63)
SM-68										
TITAN		x	x	x			x	Procedural checklist	Narrative summary	498, 499,
II	x				x		x	Workspace checklist	Narrative summary	510, 512,
ICBM	x	x	x	x	x		x	Interview	Narrative summary	513, 515,
WS-					x	x	x	Environmental record	Narr./desc. stat.	530, 532,
107C	x	x		x			x	Rating scales	Descriptive stat.	533, 545,

EQ. Equipment Design TR. Training PS. Personnel Selection TO. Operating Procedures
EN. Environmental Factors ST. Static DY. Dynamic

Table XIV. Detailed Summary of Human Performance Assessment Practices in Air Force Missile Systems (continued)

System Nomenclature	Human Performance Focus/Use					Assess. Situation		Assessment Practices		Ref. and Time Period
	EQ.	TR.	PS.	TO.	EN.	ST.	DY.	Data Collection	Data Reduction/Eval.	
TITAN	x	x			x		x	Maint. log. obs. repts.	Descriptive statistics	546, 547,
II	x	x	x				x	AFTO 210, 211 forms	Descriptive statistics	548
ICBM	x		x	x			x	Individual summary fms.	Narr./tab./desc.stat.	(1963-64)
WS-	x	x	x	x	x		x	Maintenance logs	Narrative summary	
107C	x	x	x	x	x	x	x	Contractor peculiar	Various, incl. EDP,	
(cont'd.)								worksheets, forms	tab runs	
								rating scales.		
MACE	x			x			x	Observation	Narrative summary	543
TM-76B	x	x	x	x	x	x	x	Checklist/rtg. scales	Tabulation, narrative	(1960)
				x			x	Time trials	Descriptive statistics	
		x	x	x			x	Interview	Cont. anal. narrative	
	x			x			x	Role playing/rehearsal	Flow/link diagrams	
	x	x	x	x	x		x	Crit. Incident anal. rpts.	Narrative, tabular	
	x				x		x	Photography	Pictorial, cont. anal.	
				x			x	Communication record.	Diagrammatic, cont.	
									anal.	
					x		x	Sound level meter and		
								octave band analyzer		
PRO-		x	x	x			x	Perf. checklist and		535
GRAM								summary form	Narrative, tabular	(1963)
279	x	x	x	x	x		x	Post test interview	Content anal. narrative	

EQ. Equipment Design TR. Training PS. Personnel Selection TO. Operating Procedures
EN. Environmental Factors ST. Static DY. Dynamic

Table XIV. Detailed Summary of Human Performance Assessment Practices in Air Force Missile Systems (continued)

System Nomenclature	Human Performance Focus/Use					Assess. Situation		Assessment Practices		Ref. and Time Period
	EQ.	TR.	PS.	TO.	EN.	ST.	DY.	Data Collection	Data Reduction/Eval.	
PROGRAM 279 (cont'd.)	x				x	x		HE checklist	Tabulation, narrative	
		x	x	x			x	Dev./diff. memo	Narrative, tabular	

EQ. Equipment Design TR. Training PS. Personnel Selection TO. Operating Procedures
EN. Environmental Factors ST. Static DY. Dynamic

sensors, (e.g., radar), and are required to query or communicate with computer aids to human decision making. One of the requirements of and on system personnel is therefore to relate closely to the computer subsystems of the electronic system. The assessment of human performance in these systems typically focuses upon problems of human vigilance, organization of groups for effective decision-making, human information handling, decision-making, and conditions for the display of information and effective workplaces.

2. Summary and Description of Information Reviewed

Table XV summarizes the twelve systems surveyed and the type and focus of the information available for this review of assessment techniques in electronic systems. No reports or other materials were available for evaluative activities that occurred in the Conceptual or Definition phases of system life. Reports of assessment plans and activities occurring in the Acquisition stage were, however, available for all systems. Category II/III test reports were available for 416L (SAGE) and the AN/GLR-1 portion of the 466L system. Evaluative activities in all systems related system and human performance to equipment design, operating (and maintenance) procedures, and various environmental factors (e.g., illumination, sound levels). Training and personnel selection interests were mentioned less frequently in the reports reviewed.

3. Detailed Findings Concerning Performance Assessment Practices in Electronic Systems

The assessment of human performance in electronic systems appears to be well organized and to utilize a wide variety of techniques, as illustrated in Table XVI. The typical set of data collection procedures involves direct observation of human performance by observer/evaluators (O/E's), the use of data collection forms such as checklists, questionnaires, and rating scales, the use of interviews, and some form of instrumented evaluation of environmental factors. Other techniques which appear to be used less often but nevertheless are quite promising in electronic systems include automatic data-recording using both computer programs to simulate missions and record system actions, and various forms of time and event recording apparatus. In addition, other unusual, (i.e., infrequently occurring), techniques include time and motion studies, photography, and the use of the AFTO 210, 211 forms for collection maintenance data.

The promise of using the built-in data collection, reduction, and/or reporting capacities of modern electronic systems should be noted in connection with this summary. Systems such as the 466L (AN/GLR-1 portion) and, more specifically, computer-based SAGE and BUIC have the capability of sensing and recording many overt control actions of the operators and of tabulating/summarizing the information in a variety of useful

Table XV. Summary and Description of Information Reviewed Concerning the Assessment of Human Performance in Electronic Systems

System/Subsystem Nomenclature	General Description	System Phase at Time of Review				Sources of Information				Reported Focus of Information				
							Documents							
		C	D	A	O	Conference	Test Plans	Test Results	General Descrip.	Equip. Design	Train-ing	Operat. Proced.	Personnel Selection	Environ. Factors
412L	Air Weapons Control System			X			X	X		X	X	X		
416L	SAGE-Air Defense			X	X	X	X	X	X	X	X	X		X
416M	BUIC-Interceptor Control System			X		X	X		X	X	X	X		X
425L	NORAD-Combat Operations Center			X		X			X	X		X		X
433L	Weather Observation and Forecast			X		X	X	X		X	X	X		X
465L	SAC Control System			X		X	X	X		X	X	X	X	X
466L	ELINT/COMINT			X	X	X	X	X		X	X	X	X	X
473L	HQ USAF Command and Control System			X					X	X		X		X
480L	Worldwide Communications			X						X	X	X	X	X
482L/431L	Air Traffic Control			X		X	X	X	X	X	X	X	X	X
483L	Air-to-Ground Communications			X			X			X	X	X	X	X
496L	Space Tracking System			X			X			X	X	X	X	X

C	D	A	O
Conceptual Phase	Definition Phase	Acquisition Phase	Operational Phase

Table XVI. Detailed Summary of Human Performance Assessment Practices In Air Force Electronic Systems

System Nomenclature	Human Performance Focus/Use					Assess. Situation		Assessment Practices		Ref. and Time Period
	EQ.	TR.	PS.	TO.	EN.	ST.	DY.	Data Collection	Data Reduction/Eval.	
Air	x	x		x			x	Motion photography	Narrative summary	550, 555,
Weapons	x	x		x			x	Direct observation	Summary statistics	566
Control	x			x	x		x	Interview	Narrative summary	(1961-63)
System	x			x	x		x	Questionnaires	Summary statistics	
412L		x		x			x	Paper/pencil tests	Summary statistics	
				x			x	Indirect obs. (CRT)[a]	Summary statistics	
		x		x			x	Perform. checklist	Summary statistics	
		x		x			x	Op. evaluation scale	Summary statistics	
SAGE Air		x		x		x		Paper/pencil tests	Summary statistics	574, 587,
Defense		x		x			x	Perf. test(job samp.)	Summary statistics	595
System		x		x			x	Perf. rating forms	Summary statistics	(1959-61)
416L										
Back-up		x		x			x	SPARS(miss. sim.)	Numerical analysis	551, 552,
Intercep-		x		x			x	Automatic record	Numerical analysis	555, 576,
tor		x		x			x	Simulation (BEF)[b]	Summary statistics	590, 592
Control		x		x		x		Paper/pencil tests	Summary statistics	(1963-64)
System	x	x		x			x	Direct observation	Summary statistics	
(BUIC)	x			x			x	Pers. interviews	Summary statistics	
416M	x			x	x		x	Questionnaires	Narrative summary	
	x			x				Time & motion stud.	Summary statistics	
	x				x			HE checklist	Narrative summary	
	x							Failure reports	Narrative summary	

EQ. Equipment Design TR. Training PS. Personnel Selection TO. Operating Procedures
EN. Environmental Factors ST. Static DY. Dynamic
a. CRT-Cathode Ray Tube b. BEF-BUIC Evaluation Facility, a high-fidelity simulation of the actual BUIC system.

Table XVI. Detailed Summary of Human Performance Assessment Practices In Air Force Electronic Systems (continued)

System Nomenclature	Human Performance Focus/Use					Assess. Situation		Assessment Practices		Ref. and Time Period
	EQ.	TR.	PS.	TO.	EN.	ST.	DY.	Data Collection	Data Reduction/Eval.	
NORAD					x	x		Workspace analysis	Narrative summary	564, 565,
Combat				x		x		Functional analysis	Narrative summary	578, 579,
Opera-	x				x	x		Mission funct. analy.	Narrative summary	580
tions				x		x		Procedures analysis	Narrative summary	(1958-59)
Center	x			x	x	x		Funct. rqmts. review	Narrative/statistical	
425L										
Weather	x					x		HE checklist	Narrative summary	557, 558,
Observ-		x		x			x	Direct observation	Summary statistics	559
ing and	x			x	x	x		Personnel interview	Narrative summary	(1962-63)
Forecast-	x			x			x	Controlled experiment	Comparative statistics	
ing					x	x		MacBeth Illumino-		
System								meter	Comparative statistics	
433L	x					x		Review maint. repts.	Narrative summary	
			x				x	Demonstration	Narrative summary	
	x	x		x			x	Photography	Visual comparison	
SAC			x			x		Task analysis	Narrative summary	560, 571,
Control		x		x			x	Perform. checklist	Summary statistics	572, 586,
System	x			x	x		x	Personnel interview	Narrative summary	588
465L	x			x			x	Automatic data rec.	Comparative statistics	(1960-64)
		x		x			x	Maint. checklist	Summary statistics	

EQ. Equipment Design TR. Training PS. Personnel Selection TO. Operating Procedures
EN. Environmental Factors ST. Static DY. Dynamic

Table XVI. Detailed Summary of Human Performance Assessment Practices In Air Force Electronic Systems (continued)

System Nomen-clature	Human Performance Focus/Use					Assess. Situation		Assessment Practices		Ref. and Time Period
	EQ.	TR	PS.	TO.	EN.	ST.	DY.	Data Collection	Data Reduction/Eval.	
Electro-	x	x		x			x	Direct observation	Summary statistics	573
magnetic	x			x			x	Personnel interview	Narrative summary	(1963)
Intellig.	x			x			x	Demonstration	Narrative summary	
System	x	x		x			x	Mission simulation	Summary statistics	
466L	x	x		x			x	Pen recorder	Summary statistics	
HQ USAF	x				x	x		Direct observation	Narrative summary	562, 589,
Command	x				x		x	Demonstration	Narrative summary	594
and	x						x	Mock-ups	Narrative summary	(1961)
Control					x	x		Illum. measures	Narrative summary	
System	x			x		x		Information flow		
473L								analysis	Narrative summary	
480L		x	x				x	Direct observation	Narrative summary	563
World-		x	x			x		Interviews	Narrative summary	(1960)
wide	x				x	x		Demonstration	Narrative/statistical	
Air					x	x		Illum. level meas.	Descriptive statistics	
Force					x	x		Noise level meas.	Descriptive statistics	
Commu-		x	x	x		x		Maint. rec. review	Narrative summary	
nications		x	x				x	Performance test	Narrative summary	
System	x				x	x		HE checklist	Narrative/statistical	

EQ. Equipment Design TR. Training PS. Personnel Selection TO. Operating Procedures
EN. Environmental Factors ST. Static DY. Dynamic

Table XVI. Detailed Summary of Human Performance Assessment Practices In Air Force Electronic Systems (continued)

System Nomen-clature	Human Performance Focus/Use					Assess. Situation		Assessment Practices		Ref. and Time Period
	EQ.	TR.	PS.	TO.	EN.	ST.	DY.	Data Collection	Data Reduction/Eval.	
Air	x					x		HE checklist	Narrative summary	554, 556,
Traffic	x			x			x	Automatic data rec.	Comparative statistics	561, 567,
Control	x						x	Structured interviews	Narrative summary	568, 569,
and				x	x		x	Checklist	Narrative summary	570, 577,
Landing				x	x		x	Questionnaires	Narrative summary	582, 583,
System	x			x			x	Time/event record	Summary statistics	584, 585,
482L/			x			x		Paper/pencil tests	Summary statistics	591, 593
431L		x				x		Maint. questionnaire	Narrative summary	(1962-64)
		x		x			x	Rating scales	Summary statistics	
		x		x			x	Direct observation	Summary statistics	
	x						x	DSL Rhyme Test	Comparative statistics	
	x				x		x	Demonstration	Narrative summary	
				x			x	Tape recorder	Summary statistics	
					x	x		Anthropom. measures	Summary statistics	
Commu-	x	x		x			x	Operations memo(O/M)	Summary statistics	581
nications		x		x			x	Maint. memo (M/M)	Summary statistics	(1963)
System	x			x	x		x	Post-test inter. quest.	Narrative summary	
483L	x	x		x	x		x	Deviation/Diff/Def. memo	Narrative summary	
Space		x	x	x			x	AFTO 210, 211 forms	Summary statistics	575
Tracking	x				x			HE checklist	Narrative summary	(1963)
System 496L										

EQ. Equipment Design TR. Training PS. Personnel Selection TO. Operating Procedures
EN. Environmental Factors ST. Static DY. Dynamic

formats. This capacity, carefully developed and provided for these systems, does not, however, appear to be used fully when the systems become operational. Some reasons given for this refer to Air Force doctrine and/or management policies, but it was also noted that there is a need to develop a "blue-suit" Air Force capability to use imaginatively the computer-based opportunities and techniques for assessing human performance in electronic systems.

F. Summary of Assessment Practices

The preceding review of evaluative practices in thirty-four Air Force and related programs illustrates a variety of techniques for acquiring information concerning human performance and of deriving meaning from the information. The tabulations of these various techniques having been made separately for each system, the purpose here is to provide a brief summary across systems. The table and figures which follow contribute to this overview.

Thirty-four practices were identified in the review of the thirty-four assessment programs. The test plans, test reports, and discussions concerning these programs indicated two general categories of techniques: those used in the collection and recording of data, and practices used for data reduction and analysis. The data collection practices are variations of indirect or direct observation in which reports, interviews, and empirical situations such as field trials, simulator studies, and experiments are used as information sources or test situations. Human observation is often instrumented or structured through the use of programmed materials: checklists, rating scales, apparatus set to measure selected conditions at pre-selected data points, etc. Often, too, the observer is remoted through the use of on-line video and sound monitors, and video and sound recordings for off-line, post-test analysis. The data reduction techniques illustrated in the system situations of this study most often involved narrative summaries in a variety of formats and the use of descriptive statistics (means, medians and associated estimates of variability). In some cases, test data were manipulated statistically in order to test hypotheses, interrelating sets of data and/or checking the statistical significance of results. In a relatively few cases, expert judgment was given as the principal means of deriving meaning from the assessment information concerning human performance. Table XVII correlates information concerning assessment techniques with the specific Air Force systems on which test information was available during this study.

The summaries graphically presented in Figures 7 and 8 are derived from Table XVII. Figure 7 makes visible, in summary form, the frequency of reported use for each assessment technique. Interview and observation techniques were named in practically all test plans and reports and were supported by various other techniques that combined interview and observation with paper and pencil check or work sheets and recording/measuring apparatus. Narrative and descriptive statistic summaries were most frequently noted in the test plans and reports reviewed.

Table XVII. Summary of Assessment Practices Reported in the Systems and Subsystems Reviewed

	Assessment Practices	Gemini B	SCF	MOL	Apollo	B-52	C-141	A-58	P-25	B-47	F-5A/B	F-4C	CH-3C	AN/APQ-24	Flight Sim.	DORA(F-111)	Thor	Atlas	Titan I	Titan II	Minuteman	Mace	Prog. 279	414L	416L	416M	425L	433L	465L	466L	473L	480L	482/431L	483L	496L
Data Collection and Recording	Interview	x	x	x	x	x	x	x		x	x	x	x			x	x	x	x	x		x	x	x		x		x	x	x		x	x	x	
	Questionnaire					x	x	x		x	x	x		x	x		x	x	x	x				x		x							x		
	Rating Scale		x						x					x	x		x	x		x	x	x		x	x								x		
	Interpersonal Perf. Chart																x																		
	Procedural Checklist		x			x			x	x							x			x	x		x	x					x				x	x	
	Design Checklist (H. E.)						x			x	x	x	x				x	x		x	x	x	x			x		x				x	x		x
	Life Support Checklist																x	x			x														
	Paper and Pencil Test					x								x										x	x	x						x	x		
	Anthropometry	x					x			x		x				x	x	x			x						x						x		
	Maint. Forms (e.g., AFTO)											x					x	x		x	x											x			x
	Maintainability Checklist																x	x			x								x				x	x	
	Deviation/Difficulty Reports																	x	x	x	x		x											x	
	Direct/Remoted Observation	x	x				x	x	x	x	x	x		x	x	x	x	x	x	x	x	x	x	x		x		x		x	x	x	x		
	Photography										x	x					x	x	x			x		x				x							
	Sound Measuring Instr.																x	x			x	x										x			
	Light Measuring Instr.																x	x			x										x	x			
	Time & Event Recording																				x	x								x			x		
	Voice Recording		x	x													x	x			x												x		
	Auto. Data Recording	x		x											x	x										x			x	x			x		
	Demonstration						x			x			x								x							x		x	x	x	x		
	Simulation	x		x		x	x									x	x	x		x	x				x	x		x		x					
	Time-Line Analyses			x	x			x					x				x	x		x	x						x								
	Task-Equipment Analyses			x	x						x						x	x		x	x						x		x						
	Diagrammatic Analyses			x	x								x				x				x						x			x	x				
	Personnel Records							x			x			x																					
	Position Descriptions										x																								
	Mock-ups	x					x			x			x				x	x			x									x	x				
	Review System Reports						x					x					x	x		x	x					x		x							
Data Reduction	Narrative Summary	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Diagrams/Flow Chart				x			x					x								x	x					x								
	Descriptive Statistics	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x	x		x	x	x	x
	Comparative Statistics	x		x		x			x			x		x	x	x				x	x							x	x				x		
	Electronic Data Processing															x				x															
	Expert/Opinion/Evaluation		x				x										x	x	x	x	x	x	x												

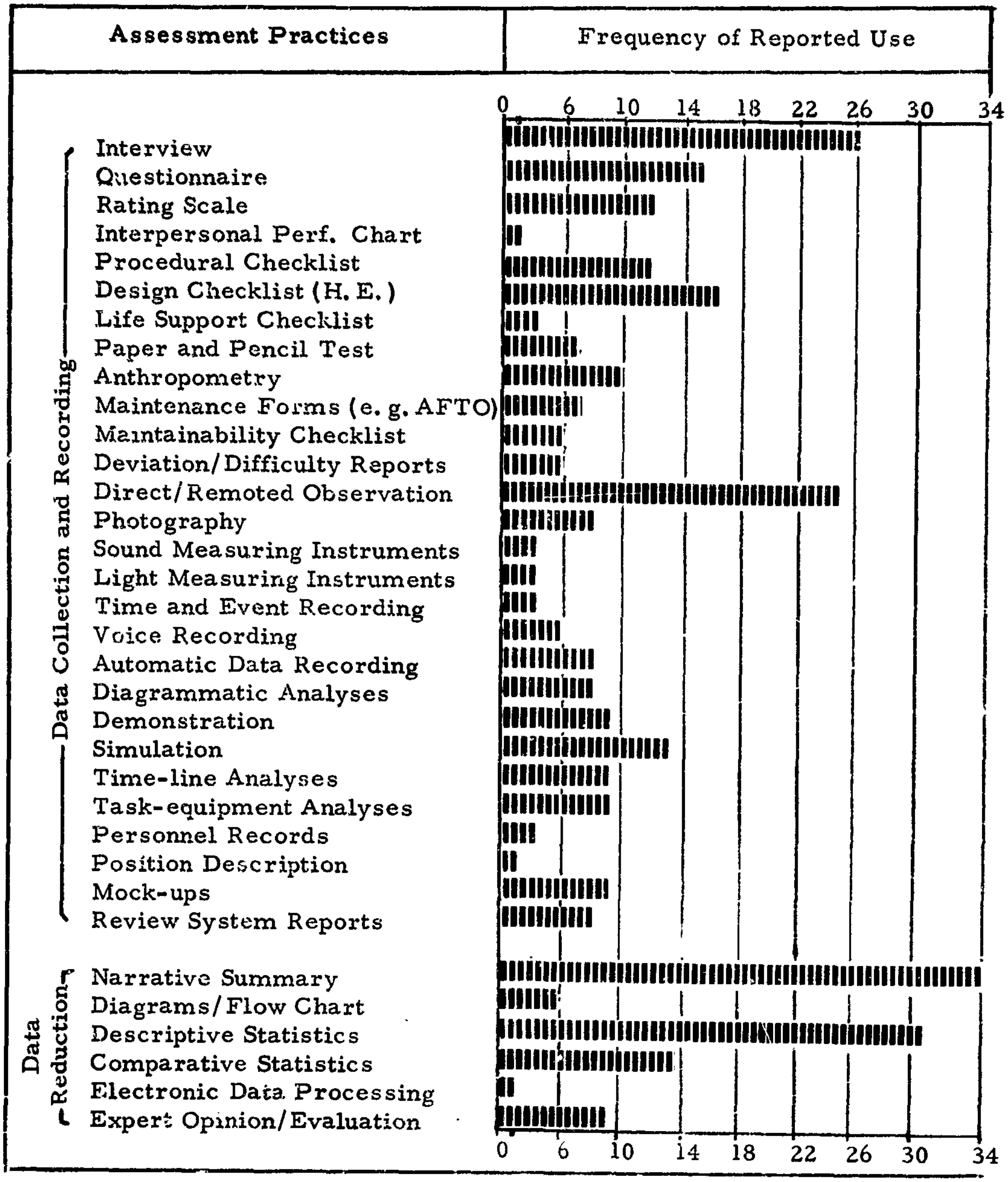
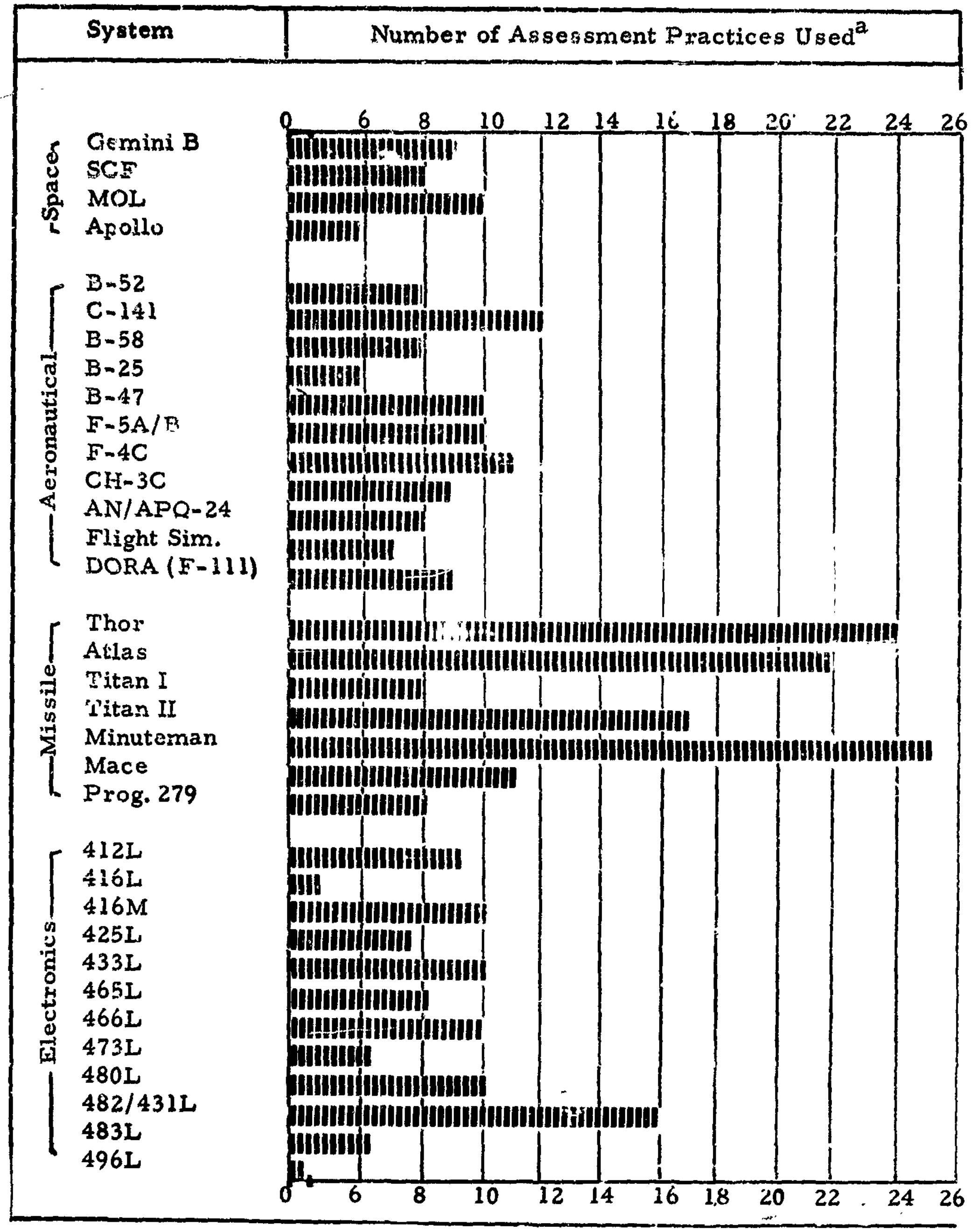


Figure 7. Frequency of Reported Uses of Human Performance Assessment Practices in the Systems Reviewed During This Study



[a]Assessment practices are summarized in Table XVII.

Figure 8. Use of Assessment Practices Among Systems Reviewed

From Figure 8 it is possible to make some comparisons among the test situations surveyed during this study. The information made available by Air Force SPO's and contractors indicated that the assessment of human performance in missile systems utilizes the largest number of the different techniques described in Table XVII. The space, aeronautical, and electronic systems noted about the same number of useful assessment techniques.

V

CONCLUDING REMARKS

A. Synopsis of Report

This report was written as a review of practices in the assessment of human performance in Air Force systems. The review was carried out during the preparation of a methodological handbook on the assessment of human performance. In order to obtain and bring together the most inclusive overview of the topic we found it necessary to (1) define operationally both human performance and the assessment of human performance in the systems context, (2) review the current Air Force policies and practices for developing and testing military systems and for developing and evaluating personnel subsystems, (3) review the methodologies of the behavioral sciences relating to human performance in the world of work, and (4) survey practices in Air Force system programs for studying human performance and/or the variables of which human performance is a function. Figure 9 summarizes these steps and the content of this report.

B. General Comments Concerning Human Performance

Our perspective herein has been that the reality that basically concerns the system scientist, behavioral or otherwise, in the development of an operable and maintainable military system is selected system PERSONNEL in the system ENVIRONMENT (which includes system equipment, ambient conditions and system personnel other than those in the focus of attention) carrying out some system ACTIVITY or procedure. These personnel-environment-activity dimensions and interactions among them constitute the subject matter of inquiries into human performance in Air Force systems. Accordingly, the subject matter breaks down into five anthropocentric areas: individual human capacities and limitations, the interaction of system personnel with each other, the interaction of system personnel and system equipment, the interaction of system personnel and the ambient system conditions, and the interaction of system personnel with the activities, procedures and work of the system. While this perspective may oversimplify the scope of human performance studies, it nevertheless seems to be useful for structuring a review of the specialists involved in the study of human performance in system contexts and the disciplines and technologies within the behavioral sciences applicable to the assessment of human performance.

C. General Comments Concerning Assessment

The assessment of human performance has been considered here as the process of analyzing and describing, collecting information concerning,

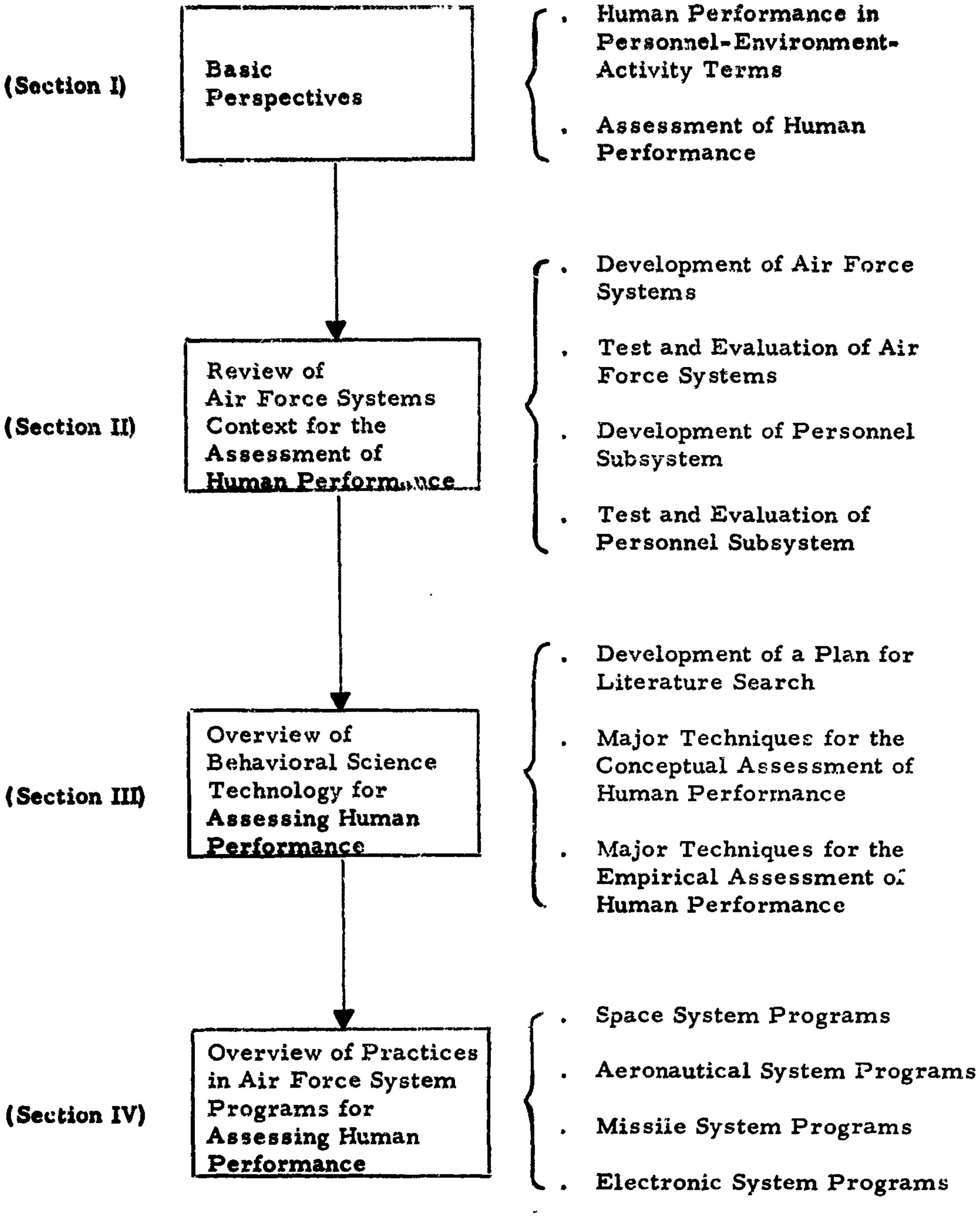


Figure 9. Content Summary of This Report

and evaluating human performance (conceived as interactions among system personnel, system environment, and system procedural dimensions). The process includes the human acquisition of information through logical assumption, indirect observation, and direct observation. The evaluation of the information requires the clear specification of the need and use for the information and the comparison of what is obtained against what is required, or previously understood, or previously not known. The use of the evaluated information very often requires consensus among the system designers and users concerning its value and meaning to system, mission performance.

The practice of this assessment methodology is well guided by rules and advice from both military and behavioral science sources. The technical decisions as to what performance information is needed and whether a test situation is required must, nevertheless, be made by the skilled specialist.

D. General Comments Concerning Assessment Technology

The assessment methodology just described is supported by a repertoire of useful techniques for getting to know about and deriving meaning from the knowledge concerning human performance in Air Force systems. The behavioral science technology contains numerous techniques that can be used in the conceptual (i.e., the human performance is conceptual) and the empirical (i.e., the human performance is observable) assessment situations. The reliability and validity of the resulting information vary and depend largely upon the care with which the test situation and instruments are developed.

Most of the techniques available and used in the behavioral sciences have been applied to assessing human performance in Air Force systems. These include a variety of techniques for data collection and reduction/analysis. The developments which are most promising for application to the assessment of human performance in Air Force systems involve the quantification of verbal and diagrammatic heuristic techniques, the use of automated laboratories, and the more widespread use of nonparametric statistical treatments.

APPENDIX I

SCHEMA FOR REVIEW OF BEHAVIORAL SCIENCE METHODS FOR THE MEASUREMENT AND ASSESSMENT OF HUMAN PERFORMANCE

Major Field No. 1 - Human Performance Studies

Basic Research Subfields

Individual Performance

- Aging
- Anthropometry
- Decision Processes
- Environmental Effects on Performance
  - Atmospheric Properties
  - Environmental Uniformity
  - Gravitation and Inertia
  - Magnetic Fields
  - Radiation
  - Thermal Effects
  - Vibration and Blast
  - Visible Spectrum
- Motivation and Stress
- Motor Performance
- Perceptual Performance
- Personality and Character Correlates
- Research Methodology and Theory
- Task and Vigilance Fatigue
- Other

Group Performance

- Group Communication Processes
- Group Decision Processes
- Group Dynamics
- Group Influence on Perception
- Group Standards and Performance
- Group Structure
- Other

Applied Research Subfields

Human Engineering

- Clothing and Personal Equipment
- Command and Control
- Communication
- Controls
- Design in Relation to the Availability of Human Resources
- Display of Information
- Equipment Acceptability
- Human Engineering Bibliographies and Handbooks
- Information Processing
- Layout of Work Places
- Maintenance
- Man-Machine Dynamics
- QQPRI Methodology
- Reconnaissance Technology
- Theory Methodology and Apparatus
- Other

Team, System Performance

- Crew Composition
- Large Organization Structure and Individual Effectiveness
- Organization Effectiveness
- Other

SCHEMA FOR REVIEW OF BEHAVIORAL SCIENCE METHODS FOR THE MEASUREMENT AND ASSESSMENT OF HUMAN PERFORMANCE (continued)

Major Field No. 2 - Personnel Research Studies

Basic Research Subfields	Applied Research Subfields
Individual Differences Criterion Theory Predictor Theory Psychometrics Other Learning and Retention Correlates of Learning Proficiency Group Factors in Learning Human Learning Activities Learning Theories and Comparative Learning Motivation in Learning Retention Transfer of Training Other	Selection and Assignment Assignment, Allocation and Distribution Procedures Career Guidance Classification Procedures Criteria Development Performance Evaluation Techniques Predictor Techniques Psychiatric Selection Research Relation to Training Requirements U.S. Military Sociology Other Training Evaluating Training Effectiveness Methods of Studying Training Requirements Task and Skill Analyses Methods Training Methods Programmed Instruction Training Aid Design Training Media Effectiveness Curriculum Planning On-the-Job and In-Class Training Procedures Other

SCHEMA FOR REVIEW OF BEHAVIORAL SCIENCE METHODS FOR THE MEASUREMENT AND ASSESSMENT OF HUMAN PERFORMANCE (continued)

Major Field No. 2 - Personnel Research Studies (continued)

Basic Research Subfields	Applied Research Subfields
	Personnel Management Adapting Available Tests to Operational Situations Design of Specific Test Batteries Determining Program Training Requirements Individual Proficiency Training Leadership Training Performance Evaluation Tests Recruitment Selection and Training for Remote Area Operations Specific Training Aid and Simulator Design Team and System Training Test Maintenance Training Foreign Nationals Other
Major Field No. 3 - Human Support and Maintenance Studies	

Bionics
Biosimulation
Techniques of Psychophysiological Monitoring
Electrical Stimulation Equipment
Other
	Maladjustment
	Accidents
	Adjustment
	Deviant Behavior
	    Character Disorders
	    Cultural Factors
	    Mental Illness
	Morale
	Other

SCHEMA FOR REVIEW OF BEHAVIORAL SCIENCE METHODS FOR THE MEASUREMENT AND ASSESSMENT OF HUMAN PERFORMANCE (continued)

Major Field No. 3 - Human Support and Maintenance (continued)

Basic Research Subfields	Applied Research Subfields
Ecology	Protective Devices
Terrestrial	Clothing and Personal Equipment
Aquatic	Motion Sickness
Atmospheric	Other
Other	
	Support Devices
Psychophysiology	Design of Space Platform
Activation Systems	Escape and Evasion
Biochemical Processes and Drugs	Prosthetic Devices
Environment Effects on Comfort, Health and Safety	Shelter Habitability
	Other
Atmospheric Properties	
Environmental Uniformity	
Gravitation and Inertia	
Magnetic Fields	
Radiation	
Thermal Effects	
Vibration and Blast	
Visible Spectrum	
Ecological Studies	
Homeostatic Systems	
Neurological	
Psychophysiological Correlates of Emotion	
Sensory	
Sleep	
Other	

SCHEMA FOR REVIEW OF BEHAVIORAL SCIENCE METHODS FOR THE MEASUREMENT AND ASSESSMENT OF HUMAN PERFORMANCE (continued)

Major Field No. 4 - Economic Analysis and Management Studies

Basic Research Subfields	Applied Research Subfields
Theory	Techniques and Methods
Decision theory	Network analysis (PERT, etc.)
Economic theory	Econometrics--methods, models, theory
Game theory	Gaming
Statistical methods	Process analysis
Graph theory	Value engineering

APPENDIX II

LISTING OF AIR FORCE REQUIREMENT DOCUMENTS STRUCTURING THE DEVELOPMENT AND ASSESSMENT OF HUMAN PERFORMANCE

Air Force Regulations

Document Number	Subject
AFR 0-2	Numerical Index of Standard Air Force Publications
AFR 0-6	Subject Index of Air Force Publications
AFR 23-2	Air Force Logistic Command
AFR 23-6	Air Training Command
AFR 26-1	Manpower and Organization Activity
AFR 26-3	Manpower Authorization, Policy and Procedures
AFR 30-5	Guidance to Insure Adequate Personnel Facilities
AFR 30-8	Development of a Personnel Subsystem for Aerospace Systems
AFR 35-14	Attending Meetings of Technical, Scientific, Professional or Similar Organizations
AFR 40-423	Non-Government Training
AFR 50-3	USAF Training for AF Contractor Employees
AFR 50-9	Special Training
AFR 50-19	Management of Training Equipment
AFR 53-12	USAF Instrument Pilot Instructor School
AFR 57-4	Modification/Modernization of Aircraft, Guided Missiles and Related Equipment
AFR 58-4	Responsibilities for Missile/Space Accident Prevention Programs

Document Number	Subject
AFR 65-3	Configuration Management
AFR 66-1	Policy, Objectives and Responsibility
AFR 66-7	Technical Order System
AFR 66-8	Maintenance Evaluation Program--Vehicles and Aerospace Ground Equipment
AFR 66-18	Contract Technical Services (CTS)
AFR 66-29	Maintainability Program for Weapon Support and Command and Control Systems
AFR 66-30	Product Improvement Program
AFR 67-19	Supply Support of Research, Development, Test and Evaluation Activities
AFR 80-5	Reliability Program for Systems, Subsystems, and Equipment
AFR 80-6	Classification of Air Force Equipment
AFR 80-11	Importance Categories
AFR 80-14	Testing Evaluation of Systems, Subsystems, and Equipments
AFR 80-24	Test Results of Commercial Equipment
AFR 80-27	Research and Development Plans and Reports
AFR 80-28	Engineering Inspections
AFR 80-31	Elimination Program for Air Force Materiel Within the Sensible Atmosphere
AFR 80-32	Quick Reaction Capability
AFR 80-36	Civil Airworthiness Standards for USAF Transport Aircraft

Document Number	Subject
AFR 122-4	Nuclear Safety - The Two Man Concept
AFR 160-3	Hazardous Noise Exposure
AFR 161-2	Aerospace Systems Management Medical
AFR 310-1	Management of Contractor Data
AFR 375-1	Management of Systems Program
AFR 375-2	System Program Office
AFR 375-3	System Program Director
AFR 375-4	System Program Documentation
AFR 400-25	Logistics Support for Other than Categories I, II, and III Tests
AFR 400-26	Logistics Support for Weapon, Support, and Control Systems Test Programs
	Air Force Manuals
AFM 11-1	AF Glossary of Standardized Terms and Definitions
AFM 26-1	Policies, Procedures and Criteria
AFM 32-3	Ground Safety - Accident Prevention Handbook
AFM 35-1	Airman Classification Manual (Vol I and II)
AFM 36-1	Officer Classification Manual
AFM 64-4	Handbook for Personal Equipment, Personnel
AFM 66-1	Maintenance Management - Depot, Field and Organizational Maintenance
AFM 66-18	Contractor Technical Services for Category II and III
AFM 110-9	System Program Documentation
AFM 172-1	Budget Administration

Document Number	Subject
	Air Force Systems Command Regulations
AFSCR 11-2	Presto Reporting System
AFSCR 80-20	Research and Development - Air Force System Command Technical Report Program
AFSCR 80-4	Status Classification of Air Force Equipment
AFSCR 80-16	Personnel Subsystem Program for Aerospace, Support, and Command and Control Systems
AFSCR 66-7-8	Depot, Field Organizational Maintenance Technical Order Data
AFSCR 80-23	Cold Weather Test Responsibility
	Air Force Systems Command Program Management Instructions
AFSCPMI 1-4	System Package Program Format
AFSCPMI 1-5	Test Report
AFSCPMI 2-5	Advanced Development Program
AFSCPMI 2-7	Job Plan Format (superceded by AFSCPMI 2-5)
AFSCPMI 4-2	In Service Engineering Procedures
AFSCPMI 4-3	Engineering Support Procedures
AFSCPMI 4-7	Engineering Service Plan Format
AFSCPMI 6-8	Status Classification
AFSCPMI 6-10	Test and Evaluation

Document Number	Subject
	Air Force System Command Manuals
AFSCM 5-1	Research and Development - Air Force System Command Technical Report Program (superseded by AFSCR 80-20)
AFSCM 80-1	Handbook of Instructions for Aircraft Designers, Vols. I and III (HIAD)
AFSCM 80-3	Handbook of Instructions for Aerospace Personnel Subsystem Designers (HIAPSED)
AFSCM 80-5	Handbook of Instructions for Ground Equipment Designers (HIGED)
AFSCM 80-6	Handbook of Instructions for Aircraft Ground Support Equipment Designers (HIAGED)
AFSCM 80-7	Handbook of Instructions for Aerospace Vehicle Equipment Design (HIAVED)
AFSCM 80-8	Handbook of Instructions for Missile Designers, Vols. I and II (HIMD)
AFSCM 80-9	Handbook of Instructions for Aerospace Systems Design (HIASD)
AFSCM 122-1	The Nuclear Weapons Safety Program
AFSCM 375-1	Configuration Management During the Definition and Acquisition Phases
AFSCM 375-4	System Program Management Manual
AFSCM 375-5	System Engineering Management Procedures
AF SCM 310-1	Management of Contractor Data and Reports

Document Number	Subject
	AFSC Division Exhibits
AFBM 57-8A	Human Engineering Design Standards for Missile System Equipment
AFBM 58-1	Contractor Report
AFBM 58-9	Inspection Requirements Manuals, Inspection Cards and Sequence Charts for Ballistic Missile Weapon Systems
AFBM 58-10	Reliability Program for Ballistic Missile and Space Systems
AFBM 59-17	Training Equipment Procurement for Air Force Ballistic Missiles and Military Space Systems
AFBM 58-18C	Quantitative and Qualitative Personnel Requirements Information
AFBM 60-1	Personnel Subsystem Testing for Ballistic Missile and Space Systems
AFBM 60-65A	Aerospace System Personnel--Equipment Data for Personnel Subsystem Development
AFBM 59-32	Design for Maintainability Program for Weapon and Space Systems
AFBSD 61-99	Human Engineering, Development of System, General Specifications for
AFBSD 62-41	System Safety Engineering: General Specifications for the Development of Air Force Ballistic Missile Systems
AFBSD 62-53	WS-133B Maintainability Design Criteria
AFBSD 62-79	Life Support Subsystem Criteria (WS-133B)
ESDP 375-1	A Typical Test Section of a System Package Program for an Electronic System

Document Number	Subject
WCLDPT 60-21	**A Technical Guide for Designers of Personnel Subsystems for Weapon/Support Systems**
WDT 56-5	**Technical Manual Program**
	Military Standards
MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-218	Technical Manuals
MIL-STD-441	Reliability of Military Electronic Equipment
MIL-STD-803A-1	Human Engineering Design Criteria for Aerospace Ground Equipment
MIL-STD-831	Preparation of Test Reports
	Military Specifications
MIL-T-4857	Training Equipment, Weapon System, Specification and Specification Compliance Test Outlines, Instructions and Requirements for Preparation of (Superseded by MIL-T-27382)
MIL-M-5474	Technical Manuals, General Requirements for Preparation of
MIL-H-6814	Handbooks, Overhaul, Electronic, Electrical Electro-Hydraulic, Electro-Mechanical Equipments, Systems, and Test Equipments, Preparation of
MIL-T-9107	Test Reports, Preparation of
MIL-D-9310	Data for Aeronautical Weapon Systems and Support Systems
MIL-W-9411	Weapon Systems, Aeronautical, General Specification for
MIL-D-9412	Data for Aerospace Ground Equipment (AGE)

Document Number	Subject
MIL-M-9864	Technical Manuals: Operation and Organizational Maintenance (Missile Weapon System)
MIL-C-9883A	Check Lists for Missile and Space Systems Operational and Organizational Maintenance
MIL-H-25946	Human Factors for Manned Aircraft Weapon Systems (Superseded by MIL-H-27894)
MIL-P-25996	Procedures for the Development of a Cockpit Subsystem and the Accomplishment of Subsystems Integration
MIL-H-26207	Human Factors Data for Guided Missile Weapon Systems (Superseded by MIL-H-27894)
MIL-D-26239	Data, Qualitative and Quantitative Personnel Requirements Information (QQPRI)
MIL-M-26512	Maintainability Requirements for Aerospace Systems and Equipment
MIL-S-26634	Specifications, Weapon System, and Support System Mock-ups, Preparation of
MIL-R-26667	Reliability and Longevity Requirements, Electronic Equipment, General Specifications for
MIL-R-26674	Reliability Requirements for Weapons Systems (Superseded by MIL-R-27542)
MIL-T-27382	Training Equipment, Subsystem, Technical Data, Preparation of (Supersedes MIL-T-4857)
MIL-T-27474	Training Equipment, Ground, General Requirements for
MIL-R-27542	Reliability Program Requirements for Aerospace Systems, Subsystems and Equipments

Document Number	Subject
MIL-T-27615	Test Outline, Engineering, for the Inspection of Training Equipment, Requirements for the Preparation of
MIL-H-27894	Human Engineering Requirements for Aerospace Systems and Equipment
MIL-S-38130	Safety Engineering of Systems and Associated Subsystems, and Equipment, General Requirements for
MIL-M-38701	Manuals, Technical, Inspection Requirements, Work Cards, for Missile and Space Weapon Systems
MIL-S-58077	Safety Engineering of Aircraft Systems, Associated Subsystems and Equipments; General Requirements for
MIL-D-70327	Drawings, Engineering and Associated Lists

APPENDIX III

DEVELOPMENT OF PERSONNEL SUBSYSTEMS IN AIR FORCE SYSTEMS: AIR FORCE POLICY, REQUIREMENTS AND DEFINITIONS (SOURCE: AFR 30-8)

Scope and Policy

Scope:

This regulation applies only to systems and programs managed in accordance with AFRs in the 375 series. However, other USAF development programs must be planned and implemented with full consideration for, and integration of, the applicable elements of personnel subsystems described herein.

USAF Policy:

a. Manpower, personnel, and training actions must be defined, scheduled, and performed in a coordinated manner, compatible with all other aspects of system development in order to provide qualified personnel at a predetermined time and place.

b. Required leadtimes for PSEs will be determined and considered in the overall system planning. The SPD will advise HQ USAF of any situation that may prevent meeting the approved System Master Schedule.

c. Contractor-furnished reports in the personnel and training PSEs will only be developed to meet requirements justified by major commands on a valid "need to have" basis. Simplicity and austerity will be the rule in development of such data. Duplication of data effort and unnecessary information and detail will be avoided (see AFR 310-1).

d. The PSEs described in this regulation are interdependent and will be developed concurrently whenever possible. Preliminary elements will be refined as permitted by development of the system.

e. The PS will be provided priorities compared with other elements of the system or program.

f. Deviations which facilitate development of the necessary PSEs, or save time or money, will be referred to HQ USAF for approval after coordination with all interested commands/agencies.

g. AFSCM 80-3, Handbook of Instructions for Aerospace Personnel Subsystem Designers will be the primary source of information and guidance for PS implementation, to the extent it does not conflict with this regulation.

Personnel Subsystem Elements

The following PSEs are usually essential in developing a system or program. The details of a PSE and its associated management milestones will differ for each program and must be defined, scheduled, prepared, integrated, coordinated and accomplished as a team effort according to AFR 375-2. No rigid sequence is intended in the order of listing of the PSEs as each is interdependent, and concurrent development is the rule rather than the exception.

a. Personnel/Equipment Data (PED):

PED is centrally controlled analytical data in the form of task and equipment information. It defines the relationship between system personnel and system hardware, other PSEs, and the technical data requirements of AFR 310-1. PED is basic to, and provides necessary data for, preparing and/or developing other PSEs.

b. Human Engineering:

Human engineering is the application of knowledge of man's capabilities and limitations to the planning, design, development, and testing of aerospace systems, equipment, and facilities to achieve optimum personnel safety, comfort, and effectiveness compatible with system requirements. It includes participation in the identification of requirements for, and in the design, development, and testing of, operator and maintenance crew stations, personnel environments, layouts, controls, displays, job procedures and performance aids. Human engineering also provides basic information and data required in the development of other PSEs.

c. Life Support (LS):

Life support in Air Force systems development includes all areas requiring special provisions for health promotion, safety, protection and sustenance of personnel employed within the total system complex. Provisions for LS should be provided for both normal and emergency operations of the system and pertain to both aircrew and ground personnel. LS is devoted to the physiological and psychological well-being of man, after his role has been established within the overall program.

Basic system design will be affected by the physiological or psychological characteristics of man. LS considerations will be included in the earliest conceptual phase. As the program progresses, LS requirements, i.e., equipment (protective and survival) and procedures, will be identified. An aggressive LS program, beginning with the conceptual phase and continuing through to the establishment of base health and safety programs, is an Air Force requirement. (See AFRs 30-5, 161-2, and 58-4.)

d. Quantitative and Qualitative Personnel Requirements Information (QQPRI):

QQPRI is personnel subsystem data used in planning for system personnel, training, and manpower. QQPRI reports will be developed, integrated, and published under the direction of AFSC with the assistance of ATC, AFLC, and the operating command(s). These reports will be time-phased to meet the requirements of ATC, AFLC, and the operating commands as identified in the System Master Schedule. QQPRI changes will be issued whenever significant changes in personnel requirements can be forecast during system/program development and test. QQPRI is normally terminated at the end of the acquisition phase or early in the operational phase. QQPRI is composed of three parts, as follows:

(1) Part I. Operations, Organizational Maintenance, and Field Maintenance.

(2) Part II. Depot Level Support. (Produced only on specific request of AFLC.)

(3) Part III. Contractor Technical Services Personnel Criteria (CTSP Criteria). This document includes long-range plans, criteria, and guidance for the utilization of CTSP in support of the operational employment of the system. It is prepared according to AFM 66-18.

e. Trained Personnel Requirements (TPR):

TPR is a tabulated list of personnel requiring system peculiar training needed to support a system through the acquisition phase and is included in the personnel training section of PTDP, PSPP, and SPP. It lists these requirements for officers, airmen, and civilians by AFSC, grade, month required, and command. Time-phasing is based on the date the

individual is required in place in the development/test, operational and support units. The TPR is initiated during the conceptual phase of program development, and refined in the PSPP at the conclusion of the definition phase and completed during the early acquisition phase when QQPRI documentation is approved by HQ USAF. The TPR is basic to the determination of training concepts and training plans, and the computation of training costs.

f. Training Concepts:

The Training Concept which appears in the PTDP will normally reflect personnel and training projections developed during the conceptual phase and USAF guidance provided in SORs and specified ADOs. In cases where the personnel training data is insufficient, the PTDP will indicate appropriate requirements for personnel subsystem efforts to be accomplished during the program definition phase. The Training Concept which appears in the PSPP reflects the combined efforts of contractors' responses to the requests for proposals and work statements of the program definition phase and of in-house studies of data available from the conceptual phase. Upon USAF approval of the PSPP, the Training Concept contained in section 10 PSPP/SPP becomes the official source document for preparing training plans and will be kept updated as the system develops throughout the acquisition phase.

g. Manpower Authorizations:

HQ USAF (AFOMO) normally allocates manpower authorizations by Program Element Code (PEC) whenever a system appears in the force structure, to fulfill the requirement of the F&FP for 5-year manpower data. Subsequent PTDP, PSPP, SPP or QQPRI documentation reflecting manpower estimates of the participating commands, must verify, or provide basis for change to the initial authorizations, as well as provide detailed individual specialty requirements such as to assure that personnel are not trained-out prior to realistic need dates.

h. System Manning and Trained Personnel Requirements (SMTPR) Plan:

(1) The SMTPR plan will reflect the total time-phased system manning and trained personnel requirements. Problems/solutions will be shown in addition to required special action or deviations from approved personnel policies, procedures and programming actions. HQ USAF will use the plan in determining availability of personnel resources within the Air Force inventory for system support. The System Manning and Trained Personnel Requirements Plan,

as a separate document, will be based on the system documentation referenced in AFR 375-4, data available from operations, training and logistics plans, QQPRI, and any other pertinent data.

(2) The SMTPR plan will include but not be limited to the following:

(a) A listing of data sources used such as program and planning documents.

(b) Manning criteria--command capability for required AFSCs retainability, oversea eligibility, security clearance. Explanation of why and/or how existing personnel resources in system or units phasing out of the inventory should or should not be used to meet the requirements of the new system.

(c) Career Field Trained Personnel Requirements, tabular listing of officers and airmen by AFSC (skill level designator not required), command, and fiscal quarter required.

(d) ORT--tabular listing of officers and airmen by AFSC, command and month required.

(e) Time-phased manning requirements by officers and airmen, by AFSC, command and month required for input to training and/or unit as applicable.

i. Training Equipment Planning Information (TEPI):

TEPI presents recommendations regarding the training equipment package defined in AFR 50-19. Copies of TEPI are provided to ATC, AFLC, and operating command(s) agencies for review. TEPI provides a basis for defining and identifying the components of the training equipment package for inclusion in the PSPP.

j. Training Equipment Development (TED):

TED includes all actions required to define, program, budget, contract, develop, produce, and acquire a system training equipment package defined in AFR 50-19. The TED will be defined during the definition phase and will be developed and produced concurrently with the system during the acquisition phase to insure timely availability to support initial and follow-on training.

k. **Training Facilities:**

Training Facilities as defined in this directive include all real estate and buildings to be utilized exclusively in support of training programs. Depending upon the nature of the system or program, facility requirements can range from the simple identification of in-being classrooms to extensive modification of existing facilities and/or complex new construction requiring additions to the Military Construction Program (MCP). Tentative identification of training facility requirements will be stated in the PTDP and refined during the project definition phase for inclusion in the PSPP/SPP.

l. Technical Publications (TP):

For the purpose of this directive, TP are technical manuals of Technical Order documents covered by AFR 66-7 which are needed to support appropriate ATC training courses. Appropriate technical publications are required at the time specified and in quantities designated by the training agencies to support training on a given system, subsystem, or major items of equipment.

m. Training Plans:

Career Field and ORT training plans are outgrowths of the Training concepts contained in the training documentation (PTDP/PSPP). These plans will set forth in detail and methods, time-phasing and requirements necessary to accomplish training in support of a system or program. Although the objectives of career field and ORT differ, the plans for each type of training will be coordinated to prevent unnecessary duplication of training/training equipment and schedule conflicts which could jeopardize programmed system test and operational dates. The schedules for training plan preparation and approval by Headquarters ATC, the preparation and approval of ORT training plans by the operating command(s)/agencies, and known start and completion dates of all training plans will be reflected in the master schedule.

n. Personnel Subsystem Test and Evaluation (PSTE):

In keeping with AFR 80-14, the following policy and procedures will apply to the test and evaluation of the PS through Category III test. Formal coordinated testing will start during Category I testing and continue through Category III testing until it is verified that the system can be operated, maintained, and supported by USAF personnel in its intended operational environment. To insure effective evaluation, consistent with overall system test objectives, a coordinated PSTE plan will be identified in the approved test plan for each system.

APPENDIX IV

TESTING/EVALUATION OF AIR FORCE SYSTEMS, SUBSYSTEMS, AND EQUIPMENTS: AIR FORCE POLICY AND REQUIREMENTS (SOURCE: AFR 30-14)

A. Objectives of Testing/Evaluation

In general, the objectives of testing and evaluation are to:

a. Measure and assess accomplishment of development objectives.

b. Assure that systems and equipment meet established requirements.

c. Obtain a true indication, forecast, or verification of the actual performance capabilities of any given system, subsystem, or item of equipment in as realistic an operational environment as practicable.

d. Insure through effective testing timely integration of operationally ready systems and support items into the active inventory in a logical order from conceptual phase through acquisition into the operational phase.

e. Detect operational and engineering deficiencies in time for changes to be incorporated prior to significant production build-up. Insure that changes to operational equipment meet the required objectives or that necessary trade-offs are identified.

f. Maintain and enhance organic capability for evaluation of systems and equipment developed to meet Air Force needs.

g. Provide testing services for Air Force agencies and non-Air-Force agencies requiring technical knowledge, capabilities, or facilities which exist primarily within USAF research and development agencies.

h. Provide data and operational analyses for application to current and future systems and system studies.

i. Evaluate the over-all logistic capability, scope, and effectiveness as prescribed by appropriate support procedures, plans, and planning factors, developed concurrently with system evolution. Acquire and evaluate data to:

(1) Verify and refine logistic procedures, plans, and/or planning factors.

(2) Enhance prospective support planning.

(3) Identify areas which will require additional impetus to insure integrated, effective system(s) logistic support.

j. Identify and assess manpower spaces and personnel resources necessary to support systems and equipment.

k. Provide training planning information, technical information, and task analysis data for the purpose of validating training and training programs.

l. Integrate hardware, software, and manpower into an entity that meets requirements most effectively (primarily for "L" systems).

B. Policies and Procedures

a. In no instance will tests be conducted without evaluation. However, evaluation may be conducted without current testing because of data available from earlier tests or other sources which may suffice, thus saving time and resources.

b. Test and evaluation will be documented and treated as a part of the system acquisition, research and development program, operational test, or engineering service effort with which it is identified.

c. Consideration will be given to the use of available commercial items in lieu of developmental items, wherever practical.

d. New and modified systems or support items, including nuclear weapons and associated equipment, will undergo test and evaluation during acquisition to determine if they meet established requirements and are:

(1) Technically sound, reliable, and safe for service use.

(2) Functionally operable, reliable, maintainable, and compatible with other systems or equipment in the environment in which the items will be employed.

(3) Able to be maintained with a minimum expenditure of resources consistent with operational requirements, e.g., manpower, support and test equipment, special tools, training, spare parts, and special facilities.

(4) Capable of being operated and maintained by Air Force personnel after completion of prescribed training.

(5) Compatible with associated warheads and other armaments as applicable.

(6) Designed to be as free as possible from design features or procedures that will evoke personnel errors in operation or maintenance.

(7) Capable of being transported by programmed mode of transportation and specific carrier equipment. Requirements of AFM 75-2 will be included as early in the test program as is feasible unless specifically exempted by HQ USAF.

(8) Designed to permit maximum ease of accessibility to equipment requiring replacement, servicing, adjustment, or calibration.

e. Test programs during the acquisition phase (Category I and II) of a given series of a system or item of equipment will be conducted under the control of the AFSC System/Equipment Program Director as appropriate. System tests will be performed by a test force or forces at one or more locations which include all agencies involved in the system.

f. Operational testing and evaluation will be scheduled for all systems, applicable subsystems, and operational support items subject to status classification (AFR 80-6). Operational support items developed in support of a validated Operational Support Requirement (OSR) will be tested by AFSC prior to operational testing by an Operating Command (AFRS 57-3, 80-2). Except for Strategic Ballistic Missile Testing (see paragraph 7), operational testing, but not evaluation, may be waived by the Operating Command if sufficient test data are obtainable from other sources.

g. Follow-on developmental tests may be required when significant changes are made in system capability, new subsystems or components are added, a system is integrated into a new environment, or changes to correct deficiencies are made, and test articles are not available during the normal test cycle; or when analysis of test data dictates verification of previously conducted tests. Provisions for such testing must be considered throughout the acquisition process (Category I and II) and planned, programmed, and executed with the priority and emphasis afforded the overall system.

h. Consideration will be given to joint experimental testing with other Services (Army, Navy, and Marine Corps) in order to insure that Air Force systems are capable of operating in a joint environment.

i. Maximum use will be made of existing test facilities and capabilities which can be made available by AFSC, the contractor(s), the participating commands, and other Government agencies. The most realistic operational environment attainable will be used for development and operational testing. Testing will be consolidated when feasible to avoid duplication. Maximum use will be made of test data available from other sources or obtained during early stages of development testing.

j. Provisions will be made for early and progressively increasing Operating and Supporting Command participation in system and subsystem development test and evaluation. This is necessary to provide familiarization, training, and experience required to achieve the earliest operational and logistic support capability. Included are Engineering Inspection Boards (AFR 80-28) and Configuration Control Boards (AFRS 57-4 and 65-3).

k. Systems and items allocated for the test inventory should be produced as rapidly as possible to permit adequate testing. Necessary changes disclosed by testing will be incorporated into production articles at the earliest practicable date.

l. Allocation and delivery of test equipment, test support equipment, or spares for systems undergoing test (Category I and II) will have precedence over production, training, or operational requirements for all equipment or personnel, except when otherwise directed by HQ USAF.

C. System Testing and Evaluation

System test programs will normally be conducted in two functional categories during the acquisition phase, and one category during the operational phase (except for Strategic Ballistic Missiles). These are:

a. Category I--Subsystem Development Test and Evaluation--consists of development testing and evaluation of the individual components, subsystems, and, in certain cases, the complete system. In addition to qualification, the testing provides for redesign, refinement, and re-evaluation as necessary, including the practicality of utilizing current standard and commercial items. These tests are conducted predominantly by the contractor but with Air Force participation, evaluation, and control exercised through AFSC. Specific examples of test objectives are the determination of:

(1) Performance, reliability, and integrity of individual components.

(2) Compatibility, reliability, and adequacy of Government Furnished Equipment (GFE), Government Furnished Aerospace Equipment (GFAE), commercial equipment, or standard Air Force items for incorporation into the system.

(3) Preliminary operating characteristics and qualitative adequacy of the system, subsystems, and components.

(4) Preliminary performance, stability, control characteristics, and general airworthiness (as appropriate) of the aerospace vehicles, or similar criteria determination for electronic and support systems/equipment.

(5) Preliminary compatibility, adequacy, supportability, and reliability of Aerospace Ground Equipment; Ground C-E-M; and commercial ground C-E and computer equipment.

(6) Preliminary maintainability and transportability characteristics of components and subsystems.

(7) Preliminary validity of personnel and training planning information used for personnel skill identification and development of manning documents, training and training equipment requirements. Additional requirements to insure personnel and training support will also be determined. Whenever feasible, formal training will be evaluated (see AFR 30-8).

(8) Preliminary identification and investigation of safety criteria for explosive ordnance and any safety problems which must be resolved before initial operational capability is established.

(9) Necessary data for preliminary handbooks/technical manuals.

(10) Preliminary evaluation of the overall logistic plans, policies, and procedures to insure consonance with the logistic concept.

(11) Evaluation of new design or updating changes.

(12) Adequacy of preliminary health hazards data and precautionary information.

(13) Procedures for prevention of and/or recovery from potentially catastrophic situations (missile and space launches, etc.).

b. Category II--System Development Test and Evaluation--consists of testing and evaluation spanning the integration of subsystems into a complete system in as near an operational configuration as is practicable. Suitable instrumentation will be employed to determine the functional capability and compatibility of subsystems. Category II is a joint contractor-Air Force effort under Air Force control during which the Air Force effort becomes predominant with ever-increasing operating and supporting command participation. Actual test operation and maintenance should be performed by military personnel who have received formal system training. It is usually culminated with the demonstration effort required to complete the development portion of the acquisition phase of a system program. Specific examples of test objectives are:

(1) Determine that the system/equipment meets established requirements and specifications for performance, control, maintenance, safety, reliability, etc.

(2) Define the operational configuration.

(3) Determine, develop, and test updating changes that are necessary to meet approved performance requirements.

(4) Refine logistic procedures and policies.

(5) Verify and validate required technical data. This term is interpreted in its broadest scope and will include prints, drawings, handbooks, manuals, technical documents, and other related publications.

(6) Evaluate new design changes before incorporation into the production system.

(7) Determine capabilities, limitations, and safety characteristics, under actual or simulated climatic conditions by ground and/or flight tests (as appropriate). These tests will be designed to yield both engineering and handbook data.

(8) Provide familiarization, experience, and limited training to Supporting and Operating Command personnel. However, primary test objectives will remain paramount.

(9) Demonstrate in the most realistic environment practicable that the complete system is operable, maintainable, and transportable

(as appropriate) with approved and minimum support and test equipment, personnel, training, special tools, spare parts, technical data, and special facilities.

(10) Determine the adequacy of the Personnel Subsystem (AFR 30-8) and accelerate actions when changes in personnel training and/or manning for the system in its operational environment are required. Verify that personnel subsystem performance is adequately supported by equipment design, tools, technical data, job environment, training, personnel selection, manning and organization control procedures.

(11) The Category II Test and Evaluation shall not be considered complete until one of the following has taken place:

(a) Performance requirements as directed by HQ USAF (Specific Operational Requirement, Development Directive, or Operational Support Requirement, etc., as applicable) have been met, and it has been demonstrated that qualified Operating Command personnel can effectively prepare, operate, and maintain the system utilizing only authorized equipment and technical procedures and data.

(b) HQ USAF has officially relieved AFSC of performance requirements that have been recommended for deletion due to advantageous trade-offs of cost or program schedule.

(c) The Operating Command and AFSC both agree there are minor areas of performance remaining that cannot be demonstrated within a reasonable time period. These may be caused by such things as long lead time components, or recent engineering changes that are not available, or extended tests and evaluations that rely on long time periods of data gathering, etc. A formal agreement must be rendered among the Operating Command(s), AFSC, AFLC, and ATC defining the uncompleted areas and showing how they will eventually be tested.

c. Category III--System Operational Test and Evaluation Program--consists of test and evaluation of operational systems under the control and direction of the Operating Command. These tests shall include all components, support items, personnel skills, technical data, and procedures and shall be performed under as near operational conditions as practicable. Suitable instrumentation will be employed in

order to adequately evaluate test results. Category III testing will be conducted utilizing a configuration as jointly agreed by the Operating Command and AFSC/AFLC. The test will be conducted in accordance with a specific test plan or order designed to meet the objectives of all participants. The test force size and composition will be as mutually agreed in the Operational Test and Evaluation Plan or Order. Accomplishment may be performed at Operating Command, AFSC, or other available installations as circumstances dictate. Specific examples of test objectives are:

(1) Determine and improve the operational capabilities of the system and develop the most effective operational tactics, techniques, doctrine, and standards.

(2) Determine any operational deficiencies and/or limitations and provide quantitative and qualitative data for product improvement programs.

(3) Evaluate the logistic system and capability. Acquire supplemental logistic data on:

   (a) The rate of parts consumption, maintenance and support facility requirements obtained during previous tests,

   (b) Adequacy of off-the-shelf equipment, as applicable;

   (c) Supportability of commercial equipment incorporated in the system;

   (d) Compatibility of equipment and components with transportation equipment planned for use in support of the equipment.

(4) Determine the adequacy of trained personnel to operate and maintain the system in its operational environment. Take action to revise the personnel subsystem and related training programs and/or manpower documents and authorizations when validated test results so indicate.

(5) Obtain supplemental data relative to operational and/or support requirements in terms of personnel; maintenance; supply; transportation; packaging and materials handling; training; special tools, test and support equipment; special facilities; general performance standards.

(6) Determine the adequacy of technical data and provide information for early corrections or additions, as found necessary.

(7) Supplement and refine reliability data.

(8) Determine the adequacy of health protection, life support, and medical and safety procedures, directives and equipment.

(9) Verify configuration status and reporting system between AFLC and supporting command where mechanized system of accounting is used.

(10) Insure that acceptable reliability factors are attained.

D. R&D Project Test and Evaluation

a. Test and Evaluation involved in the Research and Development program (Research, Exploratory Development, Advanced Development, Engineering Development, and certain Management and Support items) will be administered and conducted as an integral part of research or development projects with which identified. Criteria by program area are:

(1) Operational Support (normally a segment of engineering development). Testing and evaluation associated with operational support items from relatively simple development and operational testing of minor support items to large-scale efforts equalling those involved in system acquisition.

(a) Testing of Operational Suppo t items will include:

1. Development Testing and Evaluation to achieve objectives similar to those noted in Category I and II system development testing, as appropriate for operational support development.

2. Operational Test and Evaluation to achieve objectives similar to those noted in Category III system operational testing, as appropriate for operational support development.

(b) Subsequent to the completion of development, test, and status classification of an operational support item, it may be specified for application to one or more new systems under development. Additional testing to determine compatibility in the

new system environment may be required and is not considered duplicative.

(2) Advanced Development--Engineering Development (other than Operational Support) and Test Instrumentation:

(a) Development Testing and Evaluation will be performed to achieve objectives of the type specified for Category I and II system development testing, as appropriate to advanced subsystem, component, and test instrumentation development.

(b) An outline of testing and experimentation necessary to accomplish the proposed development will be included in the planning documentation specified in AFR 80-27. As with Exploratory Development and Research projects, statements of resources and facility requirements will be provided.

(3) Exploratory Development and Research Projects:

(a) Research Testing or Experimentation will be performed to verify hypotheses and proposed solutions to operational needs or to measure phenomena in the acquisition of new knowledge, as appropriate, but not beyond the intent as included in AFR's 80-27 and 80-4.

(b) An outline of testing and experimentation necessary to accomplish proposed research will be included in the planning documentation specified in AFR 80-27. Resources and facilities required for performing the testing and experimentation will be included in the documented plan.

E. Engineering Services Test and Evaluation

Testing services, provided to Air Force and non-Air Force agencies requiring technical support, facilities, and knowledge which exist primarily within USAF research and development agencies will be considered as engineering services. These services, which are not identifiable with an approved Air Force research and development program, will be provided in accordance with applicable support agreements or the importance of the task as determined by precedence rating, national interest, or as directed by HQ USAF, to support:

a. Operational engineering activities, which include "Unsatisfactory Report" engineering, modification engineering, re-procurement support, and evaluation of inventions and techniques.

b. Engineering support of other Air Force and DOD agencies, Government (including AEC and NASA) and industrial agencies.

c. The Defense Standardization Program (AFR 73-1).

F. Strategic Ballistic Missile Testing

In addition to the provisions of this regulation, certain testing identification and terminology will apply exclusively for reports to JCS/OSD on strategic ballistic missile testing. As shown in attachment 1, these included R&D tests (equivalent to Category I and II), DASO tests (equivalent to Category III); plus Operational tests and Follow-on Operational Tests, which are explained as follows:

a. Operational Tests. Testing and evaluation of systems reliability for Single Integrated Operations Plan (SIOP) of operational systems committed to the SIOP. The objectives of these tests, conducted by the Operating Command, are to determine the readiness, launch, inflight reliability, and accuracy of each weapon system. A sufficient number of tests will be conducted to achieve the objectives with the confidence levels as directed. Operational Tests will be accomplished subsequent to DASO tests and will be conducted in as near an operational environment as possible. Units and missiles tested will be representative of each respective missile force. Specific objectives will be identified in a Test and Evaluation Plan (for each weapon system) submitted to HQ USAF for approval.

b. Follow-on Operational Tests. These tests consist of continuing testing and evaluation by the Operating Command. The objectives of these tests are to insure that the reliability of each respective weapon system is preserved and planning factors remain valid for continued SIOP use. Any additional objectives will be identified in the Test and Evaluation Plan (for each weapon system) submitted to HQ USAF for approval. These tests will sample each ballistic missile weapon system on an annual basis. Tests will be conducted in sufficient number under an operational environment representative of the missile force to reveal any change in weapon system performance.

APPENDIX V

COGNIZANT PERSONNEL WITH WHOM DISCUSSIONS WERE HELD DURING THE SURVEY

Name	Affiliation
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B. Wolin	Systems Development Corp. Santa Monica, California

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Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1 ORIGINATING ACTIVITY (Corporate author) Dunlap and Associates, Inc. Darien, Connecticut	2a REPORT SECURITY CLASSIFICATION UNCLASSIFIED; 2b GROUP N/A

3 REPORT TITLE

CONCEPTS AND PRACTICES IN THE ASSESSMENT OF HUMAN PERFORMANCE IN AIR FORCE SYSTEMS

4 DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final report, September 1964 - April 1965

5 AUTHOR(S) (Last name, first name, initial)

Keenan, James J.
Parker, Treadway C.
Lenzycki, Henry P.

6 REPORT DATE	7a TOTAL NO OF PAGES	7b NO OF REFS
September 1965	186	595

8a CONTRACT OR GRANT NO. AF 33(615)-1754	9a ORIGINATOR'S REPORT NUMBER(S) Dunlap & Associates, Inc. report number SSD 65-172(514)R
b PROJECT NO 1710	
c Task No. 171006	9b OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
d	AMRL-TR-65-168

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11 SUPPLEMENTARY NOTES	12 SPONSORING MILITARY ACTIVITY
	Aerospace Medical Research Laboratories, Aerospace Medical Division, Air Force Systems Command, Wright-Patterson AFB, Ohio

13 ABSTRACT

This report describes the current practices and evaluation aspects of human performance assessment in Air Force Systems. The human performance test programs for thirty-four systems and subsystems representing the major types of systems (aeronautical, electronic, missile, and space) used by the Air Force are reviewed. For these systems, the major functional areas covered include: (1) Air Force policies, directives, requirements, and constraints concerning the development and assessment of system tests and human performance; (2) the behavioral sciences approach to, and technology for, assessing human performance; and (3) Air Force practices in assessment of human performance. Throughout, the systems context, within which human performance is conceived and evaluated, is emphasized. Consequently, the techniques within the behavioral sciences for examining human performance conceptually and empirically in the system test environment is a particularly practicable part of the report. The report is supported by many useful tables and charts, excerpts from test directives pertinent to human performance assessment, and approximately 600 categorized references.

DD FORM 1 JAN 64 1473

AF-WP-B-AUG 64 400

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